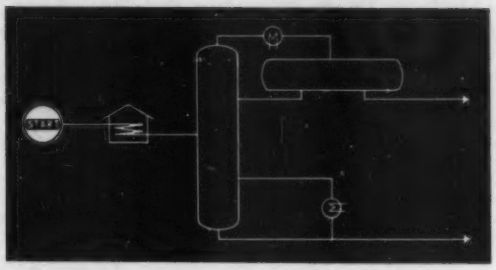
LATEST PROCESS DEVELOPMENTS



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OIL, GAS AND PETROCHEMICAL PROCESSING

Petroleum Refiner

SEPTEMBER 1959

NEW METHOD

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Beware Process Explosion Hazards 361

For a "Quick Look" at this issue, turn the page . . .

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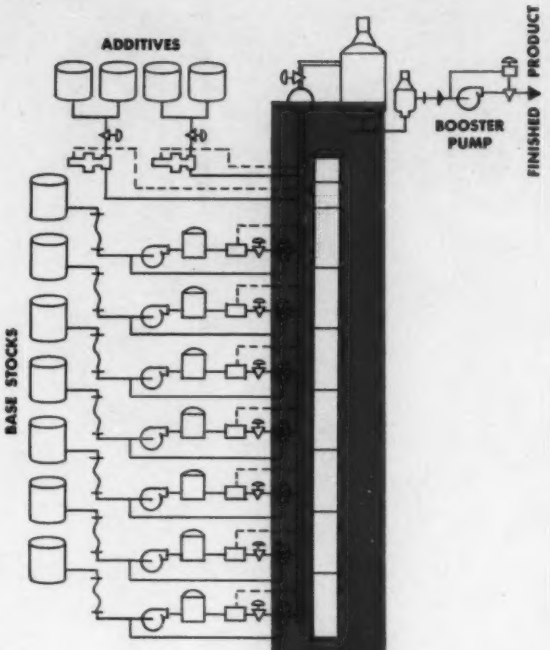

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Petroleum Refiner
OIL, GAS AND PETROCHEMICAL PROCESSING

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A Quick Look . . .

at This Issue

REFINING PROCESS DEVELOPMENTS '59

☐ **Alkylation Now Goes After Propylene . . .** There is a big shift in alkylation to include propylene in the butylenes feed. Since most new units will be designed with a mixed feed in mind, you will want to keep up with this development. This article will tell you what happens when propylene is part of the alky charge. **Page 166.**

☐ **Considering a Catalyst Change Soon? . . .** When new catalyst is added to an on-stream fluid catalytic cracking unit, it must be done gradually. Therefore, the replacement takes so long that it is difficult to evaluate which changes can be attributed to the new catalyst. Here is how one refiner handled this situation in a commercial size unit. **Page 169.**

☐ **Need Hydrogen? Examine This Process . . .** This process furnishes the hydrogen needed for treating American Gilsonite's unique feedstock. Look it over. It can be the answer to other refiners who need more hydrogen. **Page 175.**

☐ **Richfield Treaters Have Flexibility . . .** Five Electrofining treaters and a Bender catalytic sweetener were built for this refinery. Here is how they treat 19 streams in units occupying only a total ground space of a 50 by 100-foot lot. **Page 179.**

☐ **A Better Way to Extract Aromatics . . .** A new solvent, sulfolane, has been tested as a substitute for diethylene glycol. Here is how the new solvent will extract aromatics for BTX production or for motor octane improvement. See how extraction can augment the octane increase from reforming. **Page 185.**

☐ **Refine Waxes For Suitable Properties . . .** The growth of the microcrystalline wax industry is due in part to the continuing improvement of wax properties. See what tests are being used to assure that wax will be manufactured to fulfill many needs. **Page 193.**

☐ **Remove Hydrogen Sulfide From Natural Gas by Freezing and Decantation . . .** A new idea in H_2S removal which sounds effective and economical. The authors give the flowsheet and operating conditions

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A Quick Look at This Issue . . .

plus a discussion of the economics. Page 199.

☐ **Additives—A Way to Quality . . .** Here is a review of what additives will do:

- In Gasoline
- In Other Fuels
- In Motor Oils
- In Other Lubes
- In Other Products

See what the experts predict for additives and how they can help postpone capital investments in refinery processing. Page 203.

☐ **Figure Multicomponent Extraction . . .** Do you know how to correlate liquid distribution data for ternary systems? For multicomponent systems? This comprehensive report by the expert, Dr. E. G. Scheibel proposes a new method to predict data for your complex systems. Page 227.

☐ **Proven Pressure Vessel Design Methods . . .** In designing high pressure- temperature vessels, try this method of analyzing the strength and ductility in creep and stress-rupture tension tests. Several vessels using this method have had no failures. Page 247.

☐ **Use Optimum Slot Submergence . . .** for minimum bubble tray column cost. While not directly proportional to column costs, it does offer several correlations for quickly determining the lowest cost column. Page 251.

☐ **Look at Ethylene Radiation Processing . . .** Here's a design example which includes process considerations and estimated costs. Page 255.

☐ **Operator's Handbook for Gasoline Plants . . .** The third part of this series tells what practical points you need to know about instruments. Written so it's easy to understand what makes a gasoline plant tick. Page 261.

☐ **How to Control Project Cost . . .** describes a method used by Dow to effectively control project expenditures from initial estimate to final construction. Page 267.

☐ **Applied Hydrocarbon Thermodynamics . . . Equilibrium Flash Vaporization Correlations for Heavy Oils Under Subatmospheric Pressure . . .** Even though the constant percent vaporized lines of the phase diagram construction charts are essentially straight lines, you can't extrapolate them to find the phase conditions at subatmospheric pressure. Here, Edmister presents methods of predicting phase relationships in the vacuum region for high boiling petroleum fractions. Page 271.

☐ **Are Level Trays Worth Their Cost? . . .** What happens when fractionation trays are not level? Here are test data on sieve trays along with some typical costs to help you decide. The authors conclude one-fourth to one-half inch tolerance is good enough for most columns. Page 281.

☐ **Specific Heats of Hydrocarbon Liquids . . .** at atmospheric pressure can be quickly determined with this nomograph using the temperature and specific gravity. Page 284.

☐ **Ideal Ks for Acetylene . . .** If you plan to design any units for the separation of acetylene from other compounds then you'll need these acetylene vaporization equilibrium constants. Here they are for pressures up to 1,000 psia and over and for a temperature range of—114.9° to 97.4° F. See Page 285.

☐ **How to Specify Protective Coatings . . .** There are seven important points to consider before writing a protective coating specification. Also, a specification is not adequate unless provision is made to check the work to verify that it meets the spec. Page 287.

☐ **These Factors Affect Exchanger Costs . . .** Type of construction, design pressure and tube layout are the most important variables which affect exchanger costs. This nomograph instantly compares 16 different combinations of these variables. Page 289.

☐ **A Look Behind Natural Gas Prices . . .** Gas prices have gone up rapidly in the past 20 years; here's what to expect in the next 10. Competition is tougher than you might think. Page 293.

☐ **The Two Processes of 'Memory' . . . How to Remember: Part 2 . . .** Recall and recognition are the two ways that you remember previously learned material. In this article you'll learn all about these two plus some valuable information about why you sometimes forget. Page 345.

☐ **Plan Early for That Startup . . .** Organization and training make for smooth startup procedure. Here's how Union Oil used them to save time and money in putting a Uniformer-Platformer onstream. Page 348.

☐ **Beware Process Explosion Hazards . . .** If the cost of preventing an explosion exceeds the probable cost of such a disaster, then it may be good business to go ahead and take the risk. Here is how you can determine whether or not an explosive situation exists in your plant, and if so, how much damage it would cause. Page 361.

☐ **Which Man Should You Promote? . . .** Here are some of the points you should take into consideration when faced with that tough decision of who should get that promotion. Page 376.

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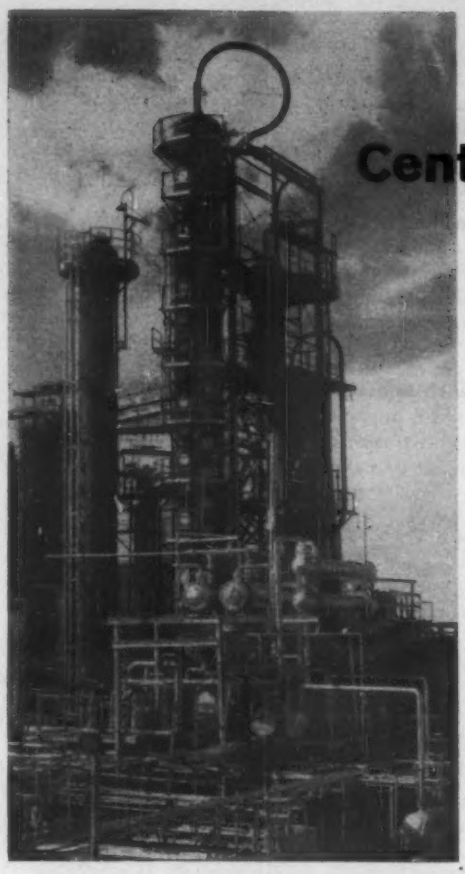

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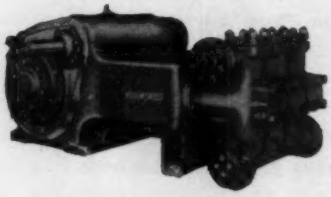
Here are Four Popular Types



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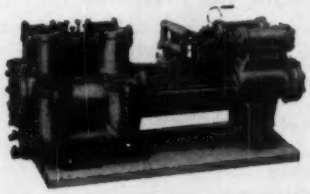

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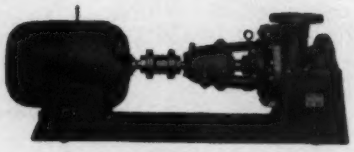
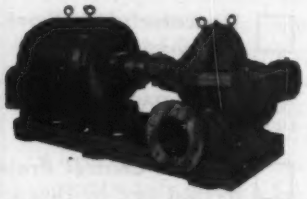


ES CENTRIFUGAL PROCESS PUMPS . . . Single or two-stage heavy-duty type for elevated temperature applications to 900°F., employing vertically split case and single stuffing box for conventional packing or mechanical seal of your choice. End suction, as illustrated, is standard construction—can also be furnished with top suction when preferred. Twenty sizes provide capacities from 15 to 2,000 GPM, 50 to 1100-ft. head, 2 to 250 HP.



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Special Special Again

YOU ARE HOLDING and reading one of PETROLEUM REFINER's highly regarded Special Issues, the Process Developments Issue which alternates in the September spot with the Process Handbook. The two complement each other, our readers tell us, and throughout the industry rate high especially for reference.

Coming along in November is the Petrochemical Handbook containing some 100 petrochemical processes, many presented for the first time. And even the repeats will be polished, shined and brought up-to-date. For these processes alone, this Handbook issue rates the tag, "Permanent Value." Readers ordinarily hang onto their copies until the next one is out.

Then in addition to the processes PR for November will contain special articles, each by an authority in his field, on the over-all petrochemical outlook, synthetic detergents, pesticides, synthetic fibers, plastics, aromatics, olefins, fluorochemicals and rubber.

It's an all-star edition, so valuable that you'd better be telling your borrow friends to use the postcard facing Page 3 and get their own subscription started soon enough to include November.

"Most Useful"

SEVERAL SCORE COPIES of PETROLEUM REFINER's Author's Handbook were made available recently at the Technical Writers' Institute, Rensselaer Polytechnic Institute, Troy, N. Y., "and quickly disappeared from our exhibition room," according to Jay R. Gould, director. "Personally, I find it most useful in my lectures on article writing," he added.

And, we might add, the technical man who writes or aspires to will find it just as useful as the man who assays an instructor's role.

Your potential as a writer for PR is perhaps much greater than you think and this valuable booklet would increase the possibilities considerably. Request *your* copy today. Address Editorial Director, PR PETROLEUM REFINER, Box 2608, Houston 1, Texas.

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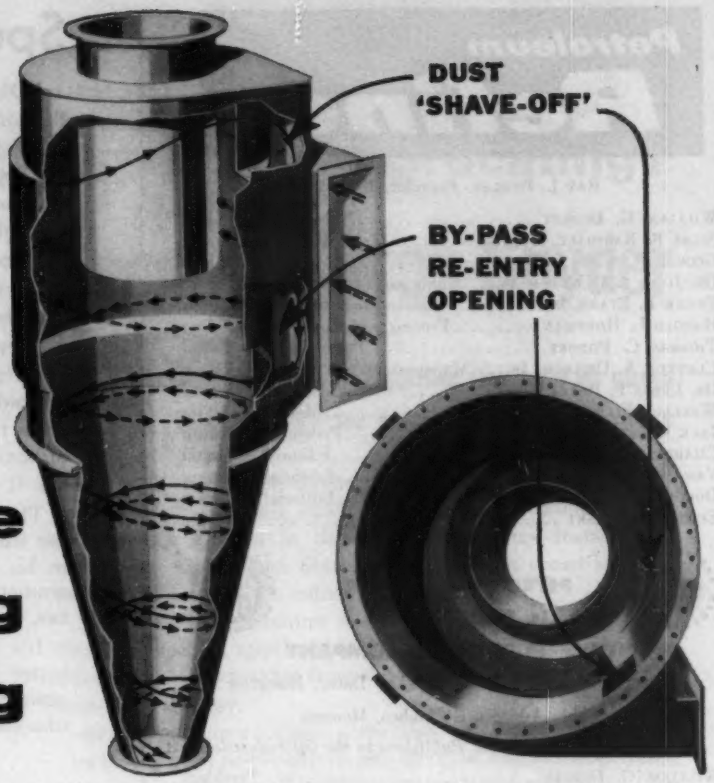
We like that quote from a PR subscriber, an assistant plant superintendent, and his further remarks that today he may be interested in boilers, air driers, cooling towers, pumps, compressors, but tomorrow, due to a change in his assignment, his chief interest will be process engineering. Whatever his job, PETROLEUM REFINER comes along each month serving "both as a textbook and a reference." If *you* don't get a *personal* copy (so, among other conveniences, you can maintain your own reference file) why not—right now—use the postcard spotted just inside the front cover?



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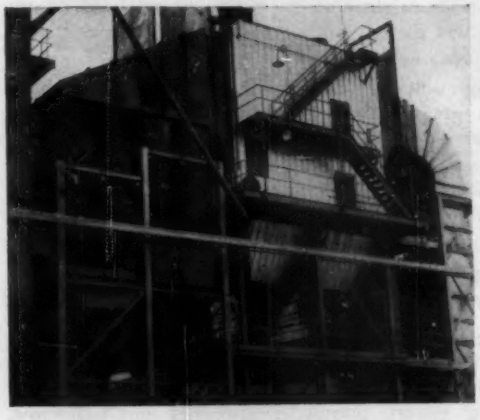

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Quick Look at Industry...

Amoco Strikes Continue . . .

At press time, workers in Amoco's Texas City and El Dorado, Ark. plants still on strike—and no closer to settlement. Management at both plants issued go back to work or be replaced ultimatum—unheeded by workers. Wages and benefits still not bone of contention—strikers claim all they want is "fair shake," i.e., maintenance of craft lines. Management claims petty grievances plus union insistence on voice in making job assignments leads to featherbedding and make-work practices (full story and pictures on page 385).

Amoco's parent, Indiana-Standard, now settled at Whiting plant and sympathy strikers at Wood River back on the job. Still struck, however, is 74,000-bpd Sugar Creek, Mo., plant.

Steel Strike May Cut Into '59 Demand . . .

Focusing briefly on the steel strike, looks as if this may cause another plague of excessive oil stocks. Reason: prolonged strikes reduce industrial demand—particularly for heavy fuels. Predictions now pegging strike in excess of 10 weeks—long enough to create product price weaknesses in 4th quarter.

But silver lining comes in form of anticipated hike in gasoline demand. Optimistic International Petroleum Asso. report pegs gasoline demand for next three months, Sept. thru Nov., at 9.5 million barrels daily—hike of 350,000 bpd (3.8%) over like period in '58. Would also be increase of 650,000 bpd over this year's May thru July demands.

Another Oil Company In Political Picture . . .

Following on Gulf Oil's heels comes Esso Standard with plan, "to inform the public on the conduct of our business and the views we hold on important public affairs." Esso's new public affairs committee will carry out 2-phase plan:

1. Keep employes informed about political and public affairs.
2. Encourage employes to exercise political rights and privileges.

Commercial shale by 1965? . . .

Late report says to look for commercial shale oil production in Colorado between 1960 and 1965. Expect initial production of 25,000 bpd to climb to 1,250,000 bpd by 1975.

Mobil Oil Family Reorganizes . . .

New regrouping plan affects principal affiliates of Socony Mobil. Magnolia in the Southwest, General Petroleum in the Far West, plus Mobil Producing in North-Central and Rocky Mountain areas now all tucked under one wing, Mobil Oil Co. No changes of ownership. (See Page 381.)

"Plowshare" Budget Restored by Congress . . .

Senate restores $2 million previously cut (PR, Aug., p. 9) from Project "Plowshare," program for nuclear explosions. Oil industry will fork up $500,000 for first part of experiment to show feasibility of crushing large shale formations with underground A-blast. Will come across with another $700,000 to $1 million later for in situ combustion phase.

National Oil on Venezuelan Scene . . .

Looks like Venezuelan national oil company is just around the corner. President Betancourt claims new company would cause no conflict between government and private companies with investments in Venezuela. Then adds, "the world's biggest petroleum exporter cannot continue without its own instrument for participating directly in the oil industry."

OCAW In at Humble . . .

After 23 years representation by independent Baytown Employes Federation, Humble Workers voted for new union—OCAW. Will represent 3,300 production and maintenance workers, but old BEF will continue to speak for some 600 clerical employes. Teamsters also filed for place on ballot, but withdrew before voting.

Giant Jersey Family Merger . . .

Giant new Humble Oil & Refining to be result of $95-million merger between Humble and Jersey Standard. Later four other Jersey affiliates, Esso Standard, Carter, Oklahoma and Pate oil companies will join new Humble, whose headquarters are expected to remain in Houston. One probable result: raising of Humble oval insignia from coast to coast (Full story on Page 382).

Panning the Building Scene . . .

Shell Oil to build new hydrotreater at Houston plant. Fluor will construct the $2 million unit which will employ Shell's "trickle flow process" . . . California Chemical planning 20-million-lb.-a-year maleic anhydride plant at Socal's Richmond, Calif., refinery—will use benzene feedstock . . . Conoco to build 50-million-lb.-a-year petrochemical plant in Lake Charles, La., to make industrial alcohols from ethylene—slated for completion in '61 . . . Canadian Oil to start construction of $4-million refinery 25 miles south of Red Deer, Alta. —plant will process 2,000 bpd crude. (More building items, Page 321.)

London Firm Buys Into Panama . . .

Lawyers now working out terms of agreement whereby Ultramar, Ltd., London, buys Panama Refining and Petrochemical, a Panamanian corp. Panama Refining owns Golden Eagle Refining, Los Angeles, and plans refinery in Panama.

Import Plan Helping Inland Refiners . . .

Oil Import Administration figures inland refiners gaining about $75 million yearly by trading imports to East Coast refineries for domestic crude. About 257,000 bpd now being exchanged for domestic crude. Assuming inland refiner makes profit of $ .80 a barrel, entire group profits $205,000 daily—thus, $75 million a year.

Quick Look Around the World . . .

Filipino investors buy 25% interest in Shell-Philippines for about $6.5 million and like interest in Shell Refining (Philippines) now planning 25,000-bpd plant in Manila . . . House passes bill calling for Public Health Service to study extent to which auto exhausts harm human life . . . Sun Oil now testing new service station pump capable of delivering nine different octane blends.

New Role for "Dacron?" . . .

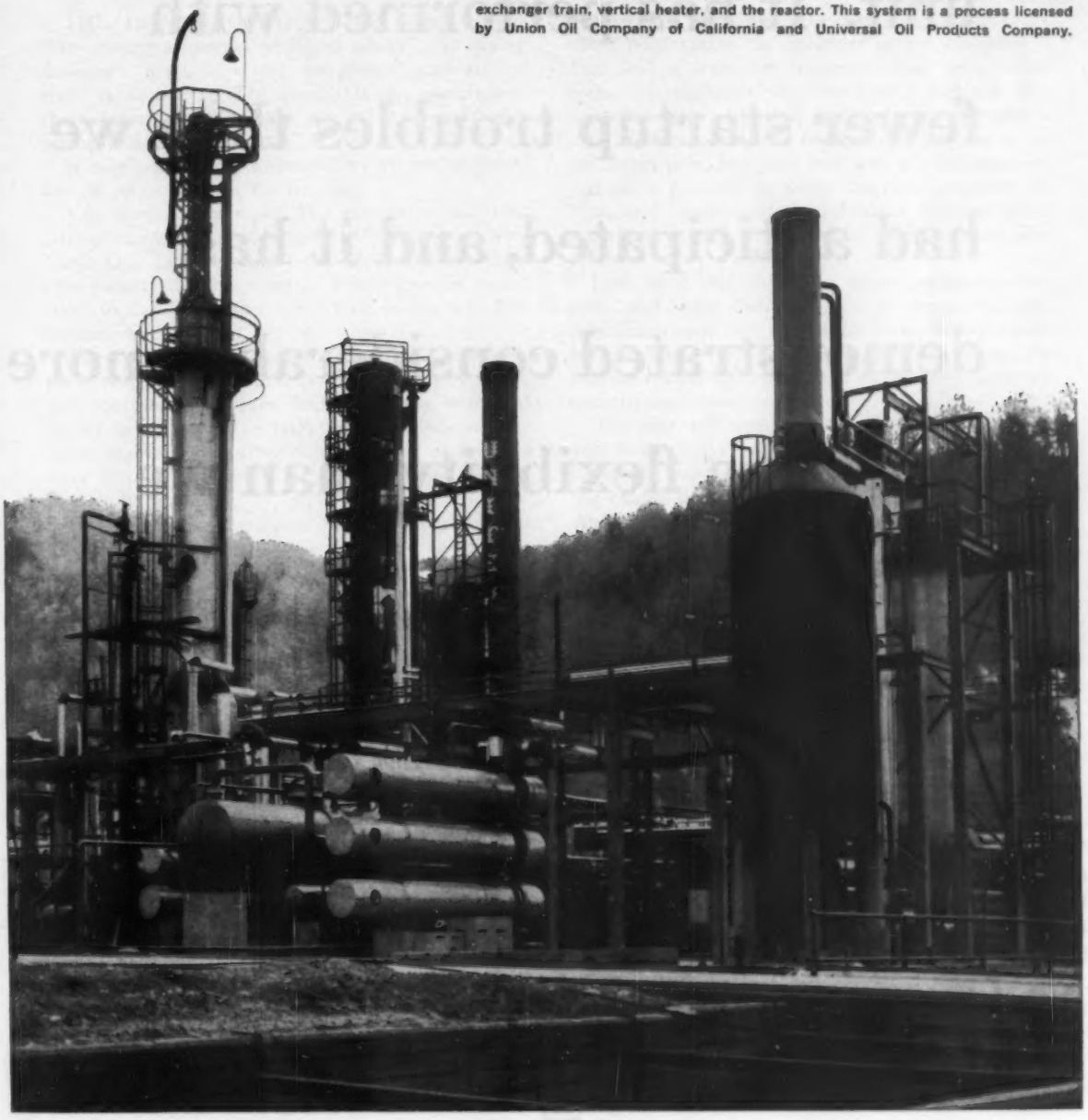
Looks as if "Dacron" may get into the rubber business. Completion of part of research program by Firestone shows the synthetic fiber may do just as well in tires as in broadcloth. According to one company official, research centered on a wide range of fibers, including acrylics—all except polyesters were eliminated in preliminary tests.

United Refining keeps expanding—first Unifiner in 1953, second in 1959—both designed by Blaw-Knox.

Now on stream: a new hydrogen treating system at United Refining Company's Warren, Pennsylvania, refinery. The system upgrades naphtha used as feed stock for catalytic reforming. The Unifiner, together with modifications Blaw-Knox made to the catalytic reformer, increases output of high octane gasoline. United Refining and Blaw-Knox worked together to install the *first* application of this process in 1953. Since then, Blaw-Knox has designed eight other hydrogen treating units with capacities ranging up to 15,000 barrels a day. Process pioneering requires a fresh outlook and technical skill found at Blaw-Knox. For details, contact Blaw-Knox headquarters in Pittsburgh, Pennsylvania. Branch offices in New York; Haddon Heights, New Jersey; Washington, D.C.; Birmingham; Chicago; and San Francisco. *Plant builders for industry . . .*

BLAW-KNOX

Unifining system comprises stripping tower (left), horizontal flasher drum and heat exchanger train, vertical heater, and the reactor. This system is a process licensed by Union Oil Company of California and Universal Oil Products Company.



For more data on advertised products, use Readers' Service Cards, last page.

A LETTER FROM SOHIO TO M. W. KELLOGG

"We are well pleased with the performance of this integrated unit. It has performed with fewer startup troubles than we had anticipated, and it has demonstrated considerably more operating flexibility than we had expected..."

(Signed) **F. J. SANDERS, Engineering Manager**
The Standard Oil Company (Sohio)
Cleveland, Ohio

The above is an excerpt from the letter of acceptance from The Standard Oil Company (Ohio) to The M. W. Kellogg Company for SOHIO's recently dedicated 60,000 BPSD refinery at Toledo. Kellogg is privileged to have been able to work with Dr. Sanders and the many others at SOHIO in making this highly integrated $40 million refinery an economic success. For those wishing to obtain the complete story on the project, write Kellogg for the SOHIO Kelloggram—a 20-page booklet devoted to the refinery's engineering, construction, and operation.

THE M. W. KELLOGG COMPANY, 711 THIRD AVENUE, NEW YORK 17, N. Y.
A SUBSIDIARY OF PULLMAN INCORPORATED

The Canadian Kellogg Company, Limited, Toronto
Kellogg International Corporation, London
Kellogg Pan American Corporation, Buenos Aires

KELLOGG

Societe Kellogg, Paris
Companhia Kellogg Brasileira, Rio de Janeiro
Compania Kellogg de Venezuela, Caracas

YOU Make the Decisions!

THE DRAFTING ROOM was crowded, but three young engineers gathered around the piping designer's table appeared completely unaware of their surroundings. The piping layout sketch was there before them as they studied a new reboiler piping design.

It might not have appeared so at the moment, but decisions were in the making.

Vacations, for example. The mountains had their advocates, as did Washington, Virginia and New York. One family would head West, another East. One would take theirs out in flying, another would stick to the '56 model car whose motor was still running like new.

They were making decisions based on knowledge, preference and experience. However, like so many of such decisions, all three knew that the wife and family would have the final vote. Nevertheless our three engineers in stating their vacation preferences were certainly sharing in a large way that decision soon to be made.

However, the real purpose of the get-together that morning was to come to some agreement on this new reboiler piping project. The vacation discussion had cropped up for a round or two of sparring before the trio tackled the real job. Engineers, and most other people, work that way.

Actually the piping problem called for an ultimate decision in the form of a joint recommendation. And that recommendation once reached would be defended by each of them as if it had been entirely his own. Process-wise there were several solutions to the problem, and the three men in that informal conference were pooling their engineering skill, knowledge and experience in hopes of arriving at the best decision, a decision which would gain most benefits for their company.

Each man defended his ideas with vigor. They were completely oblivious of others in the drafting room. Truly, this was "their cup of tea"—each was well qualified to speak. A decision was being made. Based on it, top management would invest thousands of dollars. Here—even if on a small scale—was responsibility, authority and management in action. Honesty and integrity was being applied in purest form.

Where Are Decisions? Have you ever asked yourself, "Who makes the decisions in my company?" And, isn't it true that frequently your answer has been, "Management" or "the boss"? However sincere this belief, it's you, the engineer who makes most of them. You may feel you are way down on the totem pole, but your boss and top management just can't be close to every company problem. So ideas and recommendations from a drafting room conference carry more weight perhaps than you think.

Look at it this way: You determine process line sizes, exchanger duty, the size of process pumps. Sometimes your boss may think these decisions have been made rather arbitrarily, but you know the definite reasons behind each of them. These decisions actually are yours.

The pipe still operator's hourly rate isn't set by you, but you do influence how many operators are required. You couldn't care less whose motor drives the charge pump, but you did select its horsepower. And all these—your—decisions are vital to the company's cost of operation and profit.

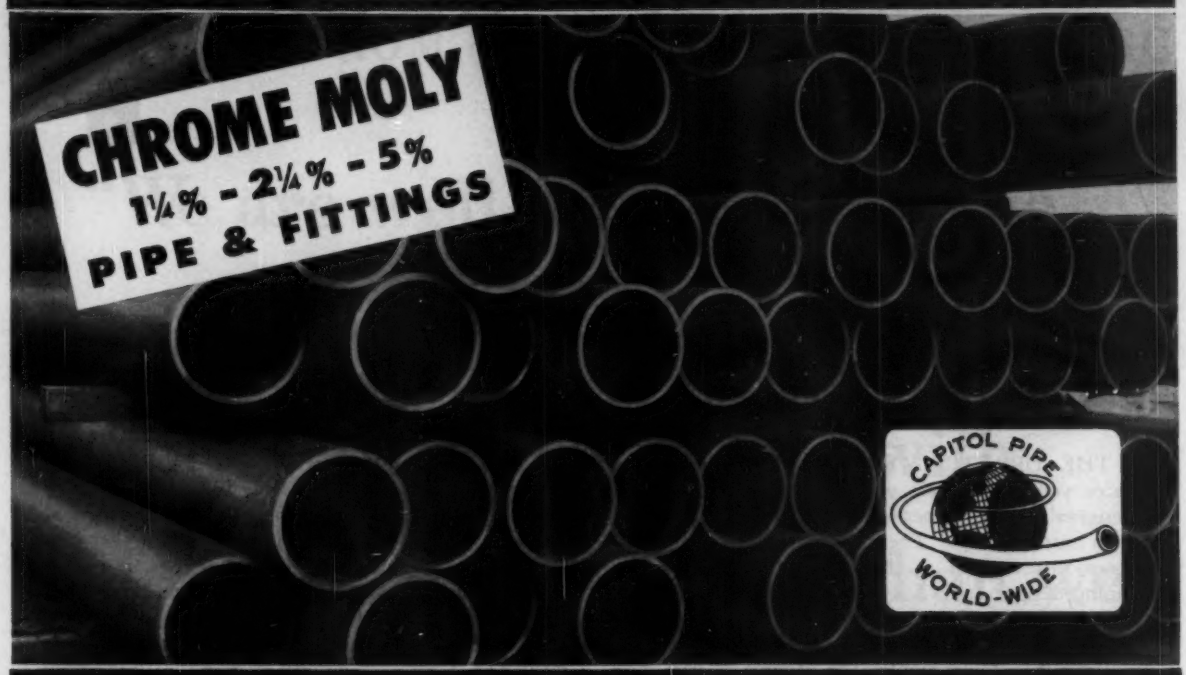
Perhaps a clerk could have made some of these decisions. However, your engineering training, knowledge and judgment is necessary in passing on these matters. Always remember you can never be too careful in exercising your judgment because in most instances it's *your* decision that will be followed. Making such engineering decisions is, of course, a part of your job.

Executing tasks as assigned is the duty of every worker, be he a trained engineer or a hod carrier. It's what his company pays for. Upon its proper execution, no matter how menial the task may seem, depends to one degree or another the success of the employing company.

And if making decisions such as we have discussed here calls for what you think is more than "normal" duty, then that in itself becomes a challenge which if met more likely than not will redound to the benefit of the engineer involved.

Obligations, Responsibility. With the privilege of making decisions comes obligations and responsibility. Your obligation? Keep in mind that your company

OUR *NEWLY INCREASED* INVENTORY PROGRAM



. . . assures you of IMMEDIATE SHIPMENTS, rather than lengthy mill deliveries and over-runs

Our long *experience* with the piping problems and requirements of Refineries, Petrochemical Plants, and Power Plants—and our exceptionally close relationship with the Piping Fabricators, Engineers, and Contractors has enabled us to *design* and *plan* our *Inventory Program* to meet the current demands for high temperature chrome moly pipe and fittings. Products of U.S.A. "top brand" manufacturers are your assurance of highest quality . . . We sell at Mill Parity Prices . . . our deliveries are very prompt.

Whether you need a length of pipe or a carload, you can rely upon Capitol day-in and day-out.

Shown above: Partial bay of 2300 feet of 14" Sch. 80 Pipe A335 P11 carried in stock

WE CARRY LARGEST STOCK OF LOW AND INTERMEDIATE CHROME MOLY PIPE ½" THROUGH 20"; SEAMLESS WELDING FITTINGS 2" THROUGH 14" —AND FORGED ALLOY FITTINGS ¼" THROUGH 2".

Capitol

PIPE & STEEL PRODUCTS, INC.

1275 SUBURBAN STATION BUILDING • 1617 PENNSYLVANIA BLVD.

RI. 6-5817 • PHILADELPHIA 3, PENNSYLVANIA

at all times deserves your best judgment. Seemingly small decisions can, in the aggregate, make a tremendous difference in the company's over-all profits. Too, decisions which require much research and digging, certainly should be given that extra effort so important both to your and your company's success.

Just as you would lose respect for your boss if he answers your requests without due consideration, your company, sooner or later, will discover to your discredit any decisions casually made. You've got to start and keep "putting something in the bank" before you can be ready for the next step upward in your company's organization. Thus little decisions go into making a man ready for a large-decision post. Your contribution, no matter how small, does have an influence on a company's over-all operation.

Responsibility to self, family and others certainly should include—and high on the list—your company. After all, barely passable work is not enough. Doing a little more and giving that extra effort is a contribution that any of us can make. Personal satisfaction in a job well done is actually greater when you know you have really added that extra touch. You are most important to you. Your success is important to your immediate situation as well as to your and your company's future. Proper performance of duty is the key to any success you might achieve. Have respect for your job and the decisions you make.

Above all, apply honesty in your deliberations. Be firm in sound convictions and state your decisions clearly. Don't ever be guilty of second-guessing with, "I wish I had mentioned this alternate."

You *are* important, and your decisions *are* important to your company's over-all operation. If the family vacation trip is a success, then part of the credit is yours because you contributed your best in helping to arrive at the correct decision. The same goes for all company moves in which you, even in a minor way, may participate.

Fine Print Worth Reading

IT'S A FEW WEEKS PAST the season of commencement which period prompted an excellent discussion in *The Wall Street Journal* entitled "A World They Never Made." However, the truths there enunciated are not changed by time and the lesson drawn is so poignant that PETROLEM REFINER asked and received permission to reproduce. Don't stop reading now, we plead, because here is another case where "the small print" is most important.

This is the season of commencement speeches, and if the speakers follow the usual pattern many of them will be deploring the mess the older generations have made of the world and exhorting the new generation to come forth and set things right.

Well, we would be the last to suggest that all is well with the world. It is torn in two, and sometimes it seems that the forces of barbarism threaten to engulf the whole of it. There is even the danger that the great allegory of Adam will come true—that being too poor in wisdom we will destroy ourselves in an atomic holocaust by the very increase in our knowledge.

Nor has our generation been immune to decay. In the realm of the spirit we have let many of the old values—the faith in the dignity and power of the individual man—wither under the preachment that Society is all and we must put our trust only in the State. We have often succumbed to the temptation to spend the nation's substance now for our own enjoyment and let the next generation worry about the long run. After all, in Lord Keynes' phrase "In the long run we are all dead."

So we would not ourselves prophesy for the next generation a tranquil life. They may have before them great economic trials. They may be called upon to die for other men's mistakes, or crimes. For all we know they may, as the prophets of doom are always saying, stand on the edge of an atomic Dark Age.

And yet, if we may intrude upon the occasion, we would like to suggest somewhat different thoughts.

The truth is, it was ever thus. In Alfred North Whitehead's words, all good things stand always upon the "razor's edge" between preservation and destruction. Western civilization, the idea of individual liberty, the concept of economic freedom that made this country rich and great, these things did not come to their present development by the road of tranquility.

It was no easy task to start this country, or to keep it whole. However romantic it may seem now on TV, it was no easy task to carve out this continent; and it is not necessary to be sentimental about the people who did it in order to recognize that they too had their moments of despair and their prophets of doom. Even recently, the fathers and grandfathers of the new generation interrupted their lives to fight two world wars against barbarism. They somehow dug their way through a depression more cruel than any of these younger people can imagine.

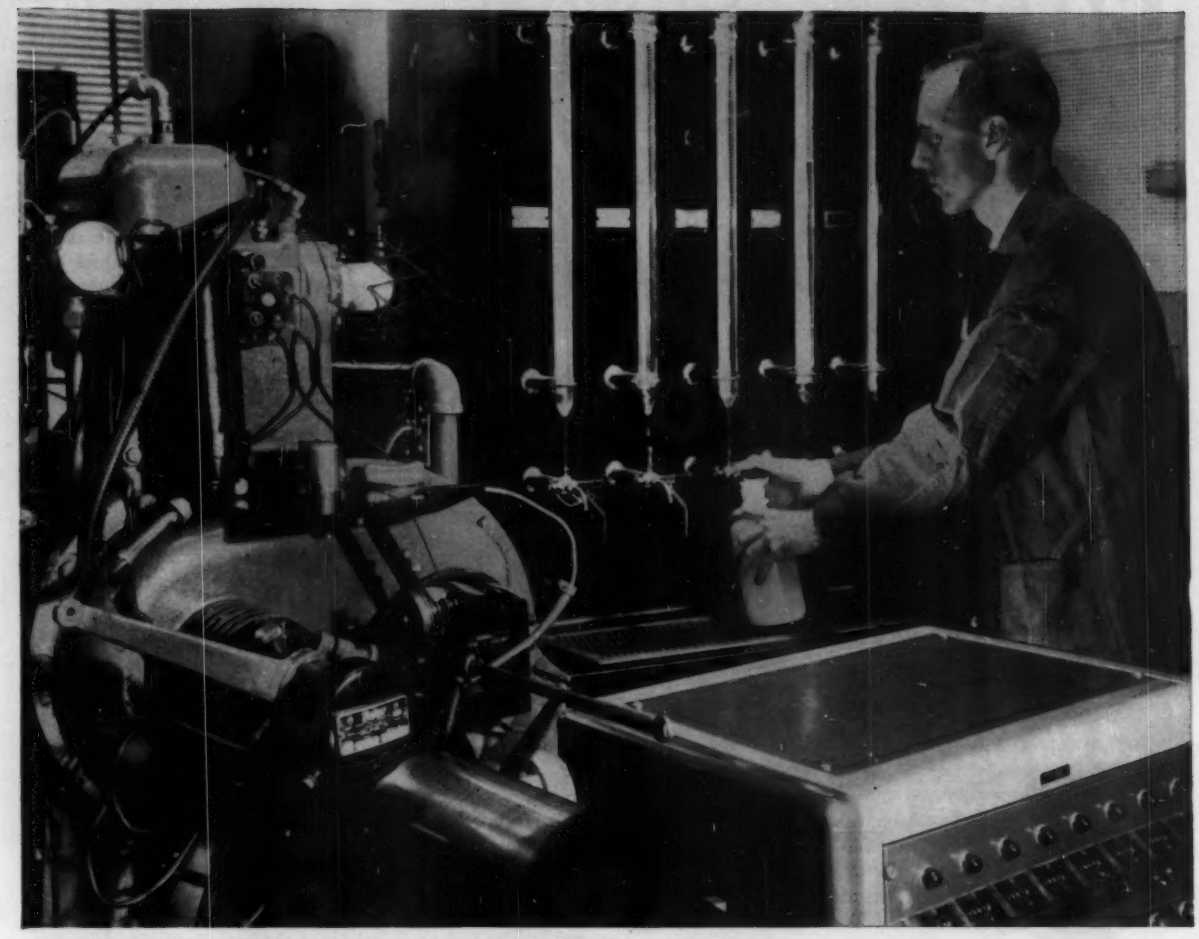
And these generations did all this with courage and with a faith that what they were suffering to preserve was something worth preserving for posterity.

It is true enough that these new graduates, as the young always like to impatiently remind us, go forth into a world they never made. But so also did they come to homes and schools and an ordered way of living in freedom, and in dignity and in peace—which also they never made. And though it is assuredly not the best of all possible worlds, it will serve. Their country, thanks to others, has not fallen to barbarism, even if it still threatens. It has not, at least so far, succumbed to the decay, even if it suffers from it.

Like any commencement speaker, we will hope the new generation will do better. But if they are to do better, we suggest they will need a regard for their own posterity and the wisdom to preserve for the future what is good in their own heritage. And to tell the truth, we will be grateful if they do as well.

Few indeed are the industrial positions wherein an engineer can work as a "lone wolf." If he honestly wishes to progress, he must be able to adapt himself to work with people until his responsibilities increase to such an extent that the major requirement is for people to work with him.

—John F. Gordon, vice president, General Motors Corporation.



The time at which a flame occurs in the combustion chamber is recorded by Ethyl —developed instrumentation. This equipment is used to study surface ignition.

Ethyl Research studies nature and control of surface ignition

ENGINE NOISE and other problems stemming from surface ignition have been obstacles to the development of more efficient engines.

In the search for ways to solve the surface-ignition problem, Ethyl Research has pioneered in the development of instruments and techniques used to study the factors causing surface ignition and to search for ways of combatting the difficulty.

Several phosphorus additives which control surface ignition have resulted from Ethyl's work in this field.

What is Surface Ignition?

It is ignition of the fuel-air charge by any source other than the normal spark; in most cases, by glowing combustion-chamber deposits. It may occur before the spark plug ignites the charge (preignition) or after normal ignition (postignition). And it may produce a single flame or many flames.

"Rumble"—The Latest Problem

A more recent problem arising from surface ignition in the modern high compression engine is "rumble"—a low frequency noise produced when surface ignition causes very rapid rates of pressure rise and high peak pressures in an engine's cylinders.

Cars with high compression engines that contain deposits from light-duty operation are subject to "rumble" during full-throttle accelerations. The noise, generally heard at speeds above 2,000 rpm, can be very objectionable to the motorist.

Factors Affecting Surface Ignition

The presence of surface ignition in an engine reflects a combination of factors. Engine design, particularly compression ratio, has an important effect on this abnormal combustion. Operating conditions also influence surface ignition. The type of deposits that cause difficulty are likely to build up most rapidly during city driving. The character of the deposits is perhaps the most important factor.

Ethyl Research has shown that de-

posits causing surface ignition are affected by composition of fuels and lubricants. Volatile oils, such as the multigraded ones, generally produce fewer deposits, and thus less surface ignition, than do oils containing heavy ends.

In fuels, the worst offenders are high-boiling hydrocarbons, particularly heavy aromatics. Heavy aromatics not only produce more deposits, but these deposits are of a type more prone to ignite the fuel-air charge.

During the past few years, the refining trend has been toward more severe catalytic reforming and the use of deeper cuts of reformate for blending high-octane motor fuels. These practices increase the percentage of aromatic hydrocarbons, thereby accentuating the surface ignition problem.

Additives to Control Surface Ignition

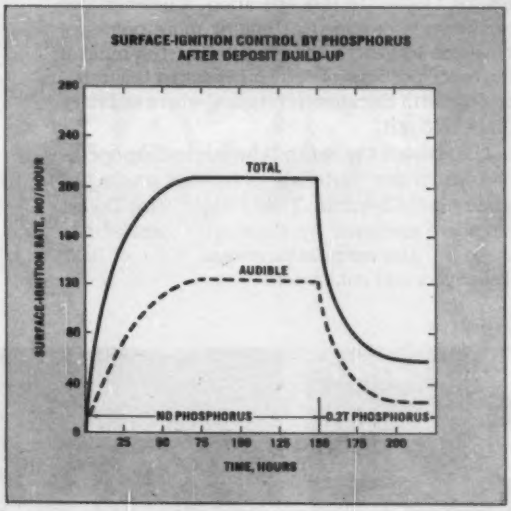
It has been known for several years that phosphorus additives are highly effective in reducing the tendencies of combustion-chamber deposits to ignite the fuel-air mixture.

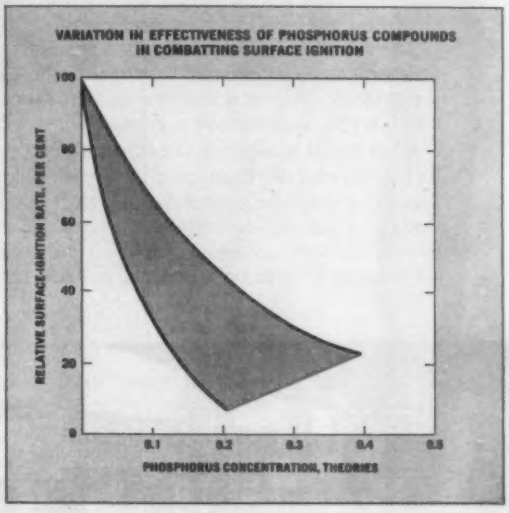
Extensive research has verified the effectiveness of phosphorus in reducing both the frequency and severity of surface ignition. Phosphorus is also effective in controlling surface ignition where deposits have accumulated before the use of the additive.

Ethyl Research has shown that different phosphorus compounds display varying degrees of effectiveness. Know-how in additive research has been applied to the screening of phosphorus additives for practical commercial use.

These screening tests include stability, solubility, inductibility, ability to combat spark-plug fouling, and possible adverse effects on engine wear, engine cleanliness, and valve life.

Phosphorus additives are widely used today. The need for them will grow as the percentage of high-compression cars increases and if the aromatic content of gasoline increases.




VARIATION IN EFFECTIVENESS OF PHOSPHORUS COMPOUNDS
IN COMBATTING SURFACE IGNITION
RELATIVE SURFACE-IGNITION RATE, PER CENT
PHOSPHORUS CONCENTRATION, THEORIES

How Ethyl Research can help you

ETHYL RESEARCH studies of surface ignition and its control are available to you through your Ethyl Representative. He will be glad to supply you with copies of our several publications on this subject, and to show the Ethyl film on "Rumble" to your technical people.

Ethyl now has three phosphorus additives that can protect your customers against surface-ignition problems. Two of these compounds are free of patent complications.

Each has its own special advantage and should be selected for your particular motor fuel requirements. These additives are backed by technical service, and extensive evaluation data on their performance are available from your Ethyl Automotive Engineer.

ETHYL

ETHYL CORPORATION
New York 17, N. Y.

Ethyl Corporation of Canada Limited, Toronto
Ethyl USA (Export) New York 17, N. Y.

RESEARCH LABORATORIES—Ferndale 20, Detroit, Michigan • San Bernardino, California

For more data on advertised products, use Readers' Service Cards, last page.

How lasting quality is Heat Exchanger

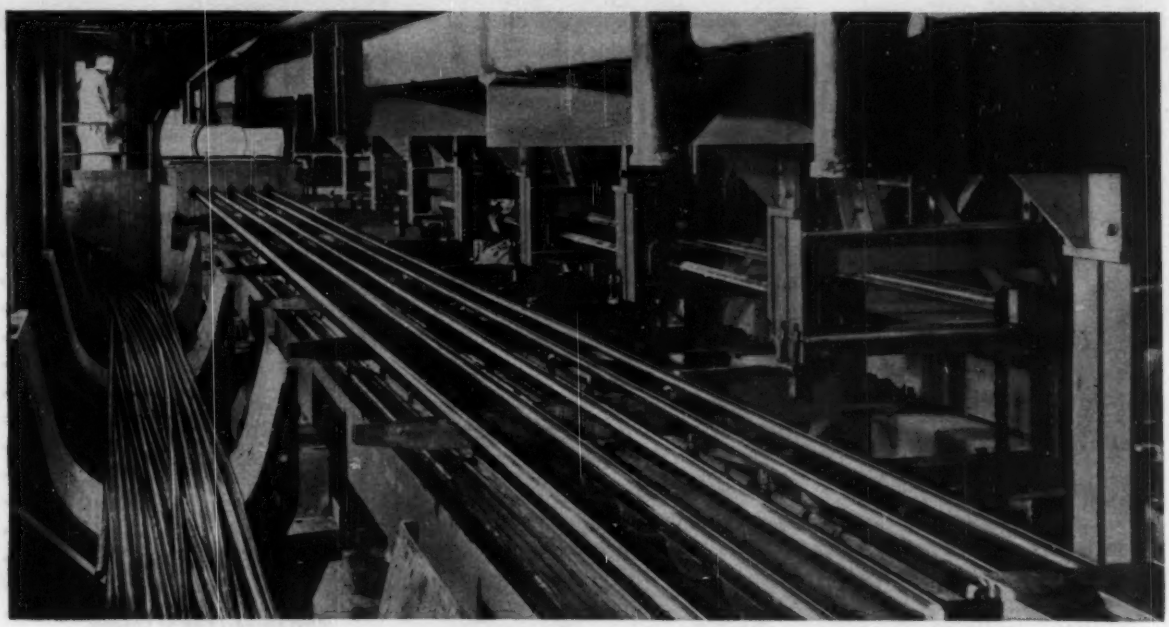
Drawing is a basic tube fabrication operation that transforms newly extruded tubes into standard and special size tubes for various applications. Phelps Dodge uses the cold-drawing process, a method in which precise control and master craftsmanship are combined to produce tubes that meet the most exacting specifications.

The cold-drawing method is used throughout, because it assures maximum tube quality through carefully coordinated operations on a drawbench where simple axial tension is applied.

After initial lubrication the tubes are brought to the drawbench. Each tube is slipped over a mandrel and hollow supporting rod, then drawn through a die and over the mandrel to form a tube of the desired diameter and wall thickness. Continuous lubrication is applied to each tube during this operation to control surface quality and minimize heat generated during the processing cycle.

Dual-gauge tubing is the result of a modified drawing operation which was developed by Phelps Dodge. In this operation, a heavier wall thickness is provided at one or more points of the tube length to compensate for thinning of the outer portions of return bends. In this manner, uniform thickness is retained where ordinary tubes thin out.

Throughout the entire tube fabricating operation—from raw materials to finished product—quality is the keynote. That's why Phelps Dodge tubes are preferred by those who demand the finest . . . the manufacturers and users of heat exchangers and condensers.

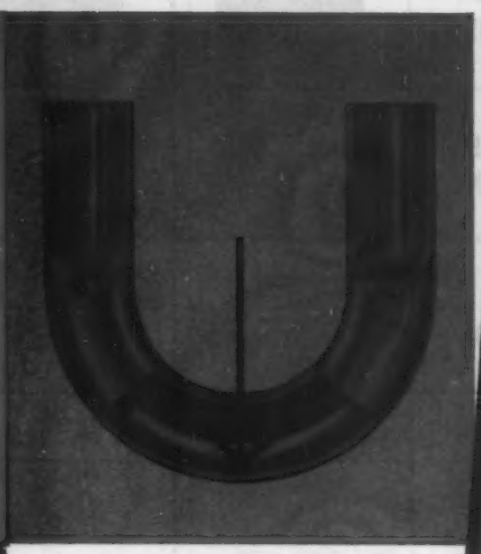


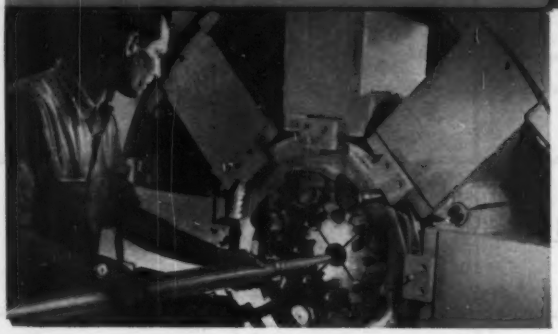
In automated drawing operation at new Phelps Dodge mill, tubes are pulled through reducing dies into smaller diameters and longer lengths.

built into Phelps Dodge and Condenser Tubes...

3 DRAWING

(THIRD OF A FIVE-PART SERIES)





Cutaway of Dual-gauge tube; note how extra metal provides additional safety factor by retaining uniform wall thickness at return bend.

Pointing one end of an extended copper shell, a preliminary step in the drawing process.

PHELPS DODGE COPPER PRODUCTS

CORPORATION

First for Lasting Quality—from Mine to Market!

SALES OFFICES: Atlanta, Birmingham, Ala., Cambridge, Mass., Charlotte, Chicago, Cincinnati, Cleveland, Dallas, Dayton, Denver, Detroit, Fort Wayne, Greensboro, N. C., Houston, Indianapolis, Jacksonville, Kansas City, Mo., Los Angeles, Memphis, Milwaukee, Minneapolis, New Orleans, New York, Philadelphia, Pittsburgh, Portland, Ore., Richmond, Rochester, N. Y., San Francisco, St. Louis, Seattle, Washington, D. C.

For more data on advertised products, use Readers' Service Cards, last page.

THE UNVARNISHED FACTS

about engine compressors in the 375 to 950 hp range

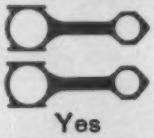
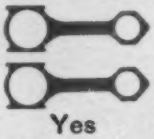
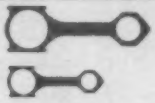
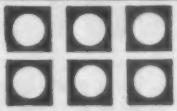
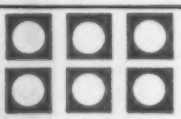
FEATURE	WORTHINGTON SLHC	MFR. A	MFR. B	MFR. C
DESIGNED FOR TURBOCHARGING	Yes	No	No	No
SELF-SUSTAINED TURBOCHARGING	YES	NO	NO	NO
FUEL CONSUMPTION	7,000 BTU/BHP HR	9,000 BTU's	8,600 BTU's	8,500 BTU's
CYCLE	4	2	2	4
CYLINDER ARRANGEMENT	Inline	Inline	Vee	Vee
RPM	450	600	450	400
YEAR ENGINE WAS DESIGNED	1955	Before 1950	Before 1940	Before 1940
NUMBER OF DESIGNS TO COVER RANGE	1	2	2	2
LARGEST UNIT FOR SKID MOUNTING	950 HP	660 HP	1100 HP	660 HP

For more data on advertised products, use Readers' Service Cards, last page.

On these two pages you'll find a comparison of all the significant facts about gas engine compressors in the 375 to 950 horsepower range. We think you'll have to agree that Worthington's SLHC unit is the outstanding performer in its size range. Not only does it have 18% better fuel economy than the next nearest engine, but it also features self-sustained turbocharging, removable cylinder liners with cast-in water jacket, interchangeable power and compressor rods, and many other important engineering advances.

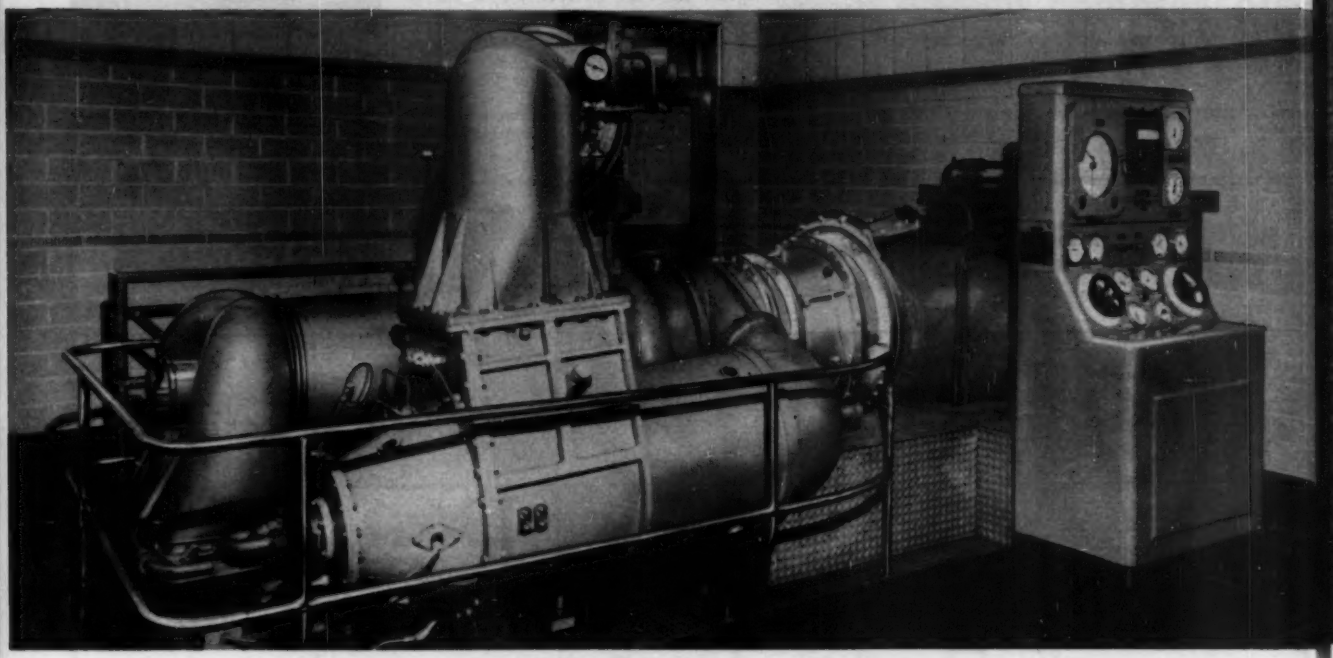
For complete details on the new SLHC engine compressor get in touch with your nearest Worthington district office. Or write to Worthington Corporation, Section 43-4, Harrison, N. J. In Canada: Worthington (Canada) Ltd., Brantfold, Ont.

WORTHINGTON

FEATURE	WORTHINGTON SLHC	MFR. A	MFR. B	MFR. C
MOUNT CYLINDERS ON BOTH SIDES	Yes	No	No	No
CYLINDER LINERS	Removable	Removable	NONE	NONE
INTERCHANGEABLE POWER AND COMPRESSOR RODS	 Yes	 Yes	No	 No
SIDE BY SIDE CONNECTING RODS	Yes	Yes	No	No
FRAME CONSTRUCTION	En-bloc	En-bloc	 Separate Cylinders	 Separate Cylinders
IGNITION	Twin	Single	Single	Single
RUNNING GEAR LUBRICATION	MANIFOLD CAST IN BASE	SEPARATE PIPE MANIFOLD	SEPARATE PIPE MANIFOLD	SEPARATE PIPE MANIFOLD
GASKET-FREE CYLINDER HEAD SEATS	YES	NO	NO	NO
RUNNING GEAR EASILY ACCESSIBLE	YES	NO	NO	NO

For more data on advertised products, use Readers' Service Cards, last page.

FIRST IN PRODUCTS PIPELINING — Up to 100,000 b/d are moved by a centrifugal pump powered by this Clark Mark TA Gas Turbine in a major products pipeline company. The Mark TA and pump do the same amount of work as two three-stage pumps in series driven by 800-hp diesels . . . and require less space, less maintenance.



CLARK MARK TA GAS TURBINES

FIRST FOR FIVE NEW POWER APPLICATIONS

A products pipeline, two widely differing mining operations, a catalytic cracker, a gas/gasoline plant join the trend to gas turbines for power in field and plant applications. And they choose the Clark Mark TA Gas Turbine because this lightweight packaged unit is demonstrating dual advantages and economies. Power generation is a prime function, but as an operating bonus, its hot exhaust gases can generate process steam, hot water and air.

There are sound reasons for the growing popularity of Clark Gas Turbines. An efficient, single combustion chamber—using gaseous or liquid fuel—provides the design simplicity and dependability required for long service life with minimum maintenance. Thermo-elastic design makes it possible to accept full load quickly without stress. Dual-shaft construction assures maximum speed flexibility for process use. Air cooling makes Clark Gas Turbines ideal for locations where short water supply is a problem.

The Clark Mark TA Gas Turbine is conservatively rated at 1220 bhp, with a normal output speed of 6000 rpm. Three other standard speed models are available. For applications requiring more horsepower, Clark 302 and 305 Gas Turbines are rated up to 9300 bhp.

Your nearest Clark representative has full information on all Clark Gas Turbine models. Or simply write for Bulletins 162 and 163-1 to Clark Bros. Co., 1330 Lincoln Ave., Olean, N. Y.

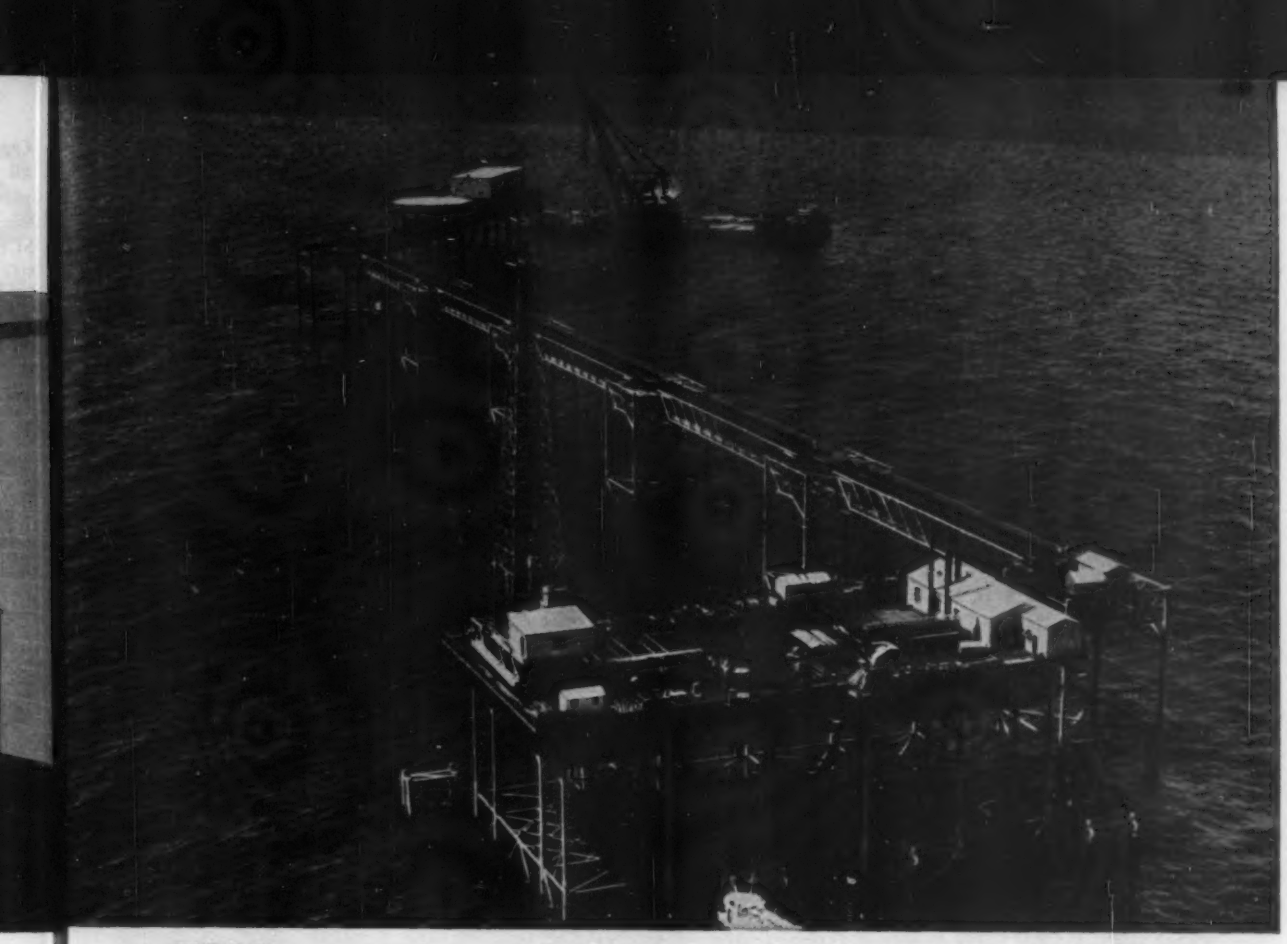
CLARK

CLARK BROS. CO.

OLEAN, N. Y.

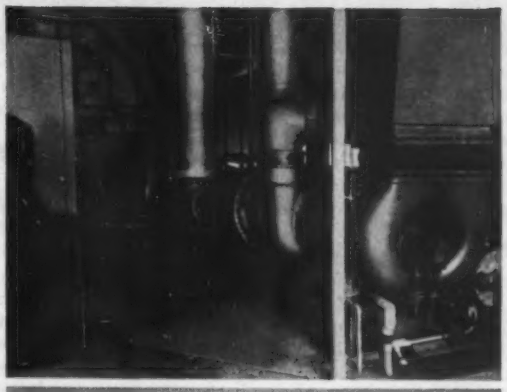
One of the Dresser Industries

COMPRESSORS • ENGINES • GAS TURBINES



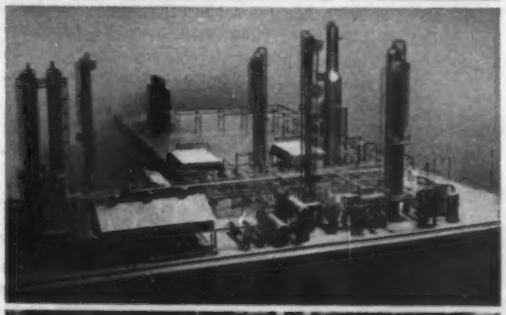
FIRST IN OFFSHORE SULPHUR MINING

Seven miles out in the Gulf of Mexico, Freeport Sulphur Company uses a Clark Mark TA as prime mover in the production of molten sulphur from a deposit 2000 feet below the surface of the Gulf. The Mark TA by driving an electric generator produced power for the drilling rig that put down the production wells (this is the first time a gas turbine has been used on an electric rig). After the main power plant is on stream, the Mark TA will continue in service: (1) Producing part of the plant electrical power used for many vital functions including powering the Clark Balanced/Opposed Compressors supplying the air which lifts the molten sulphur to the surface. (2) Supplying the boilers with hot combustion air which, with supplementary fuel, will generate the steam necessary to heat 5 million gallons of water per day used to melt the sulphur deposit.



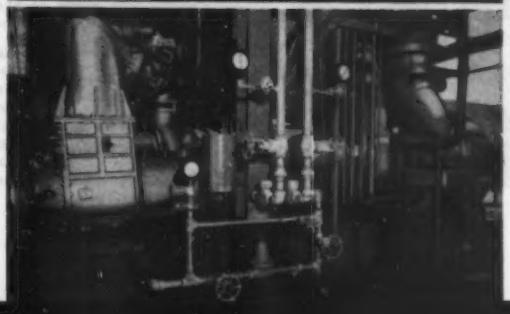
FIRST IN OPEN PIT MINING

This Clark Mark TA driving a generator not only supplies electricity for operation of the Greybull, Wyoming, installation of the Magnet Cove Barium Corporation, but in addition its exhaust gases are used for drying ore. Even discounting the ore-drying bonus, the mine manager reports "better than anticipated fuel economy."



FIRST IN GAS/GASOLINE PLANT

All electric power requirements plus generation of process steam in a waste heat boiler will be accomplished by a Clark Mark TA in the gas processing plant now being constructed for Sun Oil Company near Laverne, Oklahoma (model shown). Initial plant capacity is rated at 100 M.M.s.c.f.d. A projected 50 percent expansion can be accomplished with the same power unit.



FIRST ON A SMALL CAT CRACKER

This Clark Mark TA, mounted outdoors, drives a cat cracker blower supplying air directly to a catalyst regenerator at the Duncan, Oklahoma, refinery of DX Sunray Oil Company. Though larger gas turbines have been used in this manner before, the Mark TA is demonstrating the efficiency of smaller applications. The Mark TA Gas Turbine is available through a licensing agreement between Ruston-Hornsby Ltd., Lincoln, England, and Clark Bros. Co.

another
TRETOLITE SERVICE
report

THESE USE-PROVEN PRODUCTS CUT MANUFACTURING AND MAINTENANCE COSTS

TRET-O-LITE* *Demulsifiers*

TRET-O-LITE Demulsifying Chemicals separate an aqueous phase from a hydrocarbon phase, or vice versa.

Separation procedure consists simply in mixing a small proportion of the selected TRET-O-LITE with the emulsion and providing suitable storage where the oil and water can separate.

TRET-O-LITE Demulsifiers are used to treat tank "bottoms," also Bunker "C" fuels for the removal of salts and trace metals to permit the use of such fuels in gas turbines.

TRET-O-LITE* *Desalting Chemicals*

TRET-O-LITE Desalting Chemicals are formulated for use in chemical desalting systems. The Tretolite Company pioneered the use of chemicals in "salt settlers", and developed the first desalting system in which chemicals alone provided the emulsion destabilizing action.

In addition to their use in chemical desalting systems, TRET-O-LITE Desalting Chemicals are widely used to provide chemical action in chemical-electric desalting, and for chemical aid to electric desalting when highly adverse treating conditions are encountered.

KONTOL* *Corrosion Inhibitor*

KONTOL Corrosion Inhibitor is a liquid organic semi-polar compound, available in various formulas. It adsorbs onto metal surfaces to form impervious corrosion-inhibiting film. KONTOL Corrosion Inhibitors prevent corrosion in hydrocarbon distillation systems by protecting against attack by chlorides, sulfides, organic acids, other corrosive agents and hydrogen blistering. They also have effective detergent properties at temperatures above those considered normal for this type of inhibitor.

*TRET-O-LITE, KONTOL *and* KUPLEX *are registered trademarks of Petrolite Corporation*
†TOLAD *is a Petrolite Corporation trademark, registration pending*

TOLAD† *Fuel Additives*

TOLAD Fuel Oil Additives are ashless, totally oil-soluble compounds designed to enhance the stability of domestic heating oil and diesel fuels, as regards color and residue. These additives exhibit excellent water tolerance characteristics reducing sludge formation and loss to water bottoms in fuel storages. They are available as inhibitor or inhibitor-dispersant formulations.

KUPLEX* *Metal Deactivator*

KUPLEX Metal Deactivator prevents the pro-oxidant effects of copper and its compounds from causing the degradation of petroleum distillates. It prevents degradation reactions by tying-up the dissolved metal as an inactive stable chelate. At concentrations as low as 8 ppm it can reduce anti-oxidant requirement and assure fuel stability. It is effective in gasoline, kerosine, jet fuel, diesel fuel, furnace oil and turbine oil.

TRET-O-LITE* *Water De-Oilers*

The disposal of refinery wastes often results in the loss of valuable refined products, may also lead to the creation of a stream pollution nuisance. Many refiners use TRET-O-LITE Water De-Oilers to correct such problems. The efficient demulsification of waste oil emulsions often makes possible the salvage of large quantities of oil, as well as the lessening of the pollution problem. Tretolite chemicals are in daily use for reclaiming oil from slop disposal systems and separator traps.

For complete information on these, or any Tretolite Company product or service, *ask the Man in the Red Car,* or write

AR-89-1R

PETROLITE CORPORATION

TRETOLITE COMPANY
DIVISIONS
359 Marshall Avenue, Saint Louis 19, Missouri
5515 Telegraph Road, Los Angeles 22, California

CANADA: Petrolite Corporation of Canada, Limited, 309 Alexandra Bldg., Edmonton, Alberta
ENGLAND: Petrolite Limited, 46 Mount Street, London, W. 1.
VENEZUELA: South American Petrolite Corporation, Hotel Avila, Caracas

REPRESENTATIVES

BRAZIL: WERCO, Ltda., Avenida Rio Branco 57-s/1410-11, Rio de Janeiro
COLOMBIA: South American Petrolite Corporation, Calle 19, No. 7-30, Office 807, Bogota
GERMANY: H. Costenoble, Guiollettstrasse 47, Frankfort, a.M.
ITALY: NYMCO S.p.A. 9, Lungotevere A. da Brescia, Rome
JAPAN: Maruwa Bussan KK, No. 3, 2-Chome, Kyobashi, Chuo-Ku, Tokyo
KUWAIT: F. N. Dahdah, Box 1713, Al Kuwait
MEXICO: R. E. Power, Sierra de Mijes, No. 125, Mexico, D. F.
NETHERLANDS: F. E. C. Jenkins, Hoefbladlaan 134, The Hague
PERU: International Gas Lift Company, Apartado 71, Talara
TRINIDAD: Neal and Massy, Ltd., Port of Spain, P.O. Box 544

Protected by L. W. Blazecrete—this structure was virtually undamaged by 2 to 6 hours of *direct* flame exposure

Protected by Johns-Manville L. W. Blazecrete . . .

vital equipment is undamaged by 3 days of explosive fire!

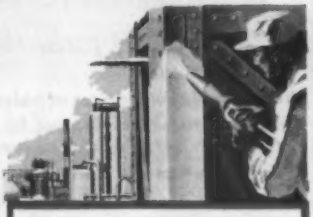
AFTER MORE than seventy hours of fire and explosion at one of the world's most modern thermofor catalytic plants, damage was estimated at nearly 8 million dollars.

Yet the flames didn't destroy the entire plant. Vital equipment, key structural members and control areas . . . made fire safe by Johns-Manville L. W. Blazecrete® . . . were virtually undamaged. This simple, low-cost protection paid for itself countless times over . . . helped get the refinery back on line many months sooner.

In your plant, too, Johns-Manville L. W. Blazecrete can save you money . . . for fire control and for lining high-temperature equipment.

A hydraulic-setting refractory—Johns-Manville L. W. Blazecrete is quickly, easily applied to equipment and structural members . . . and to linings of high-temperature equipment. For troweling, just mix L. W. Blazecrete with water as you'd mix ordinary concrete—then slap trowel in place. When gunned, L. W. Blazecrete adheres readily with a minimum of rebound loss. Whether used for fire protection or for linings—L. W. *Blazecrete lasts!*

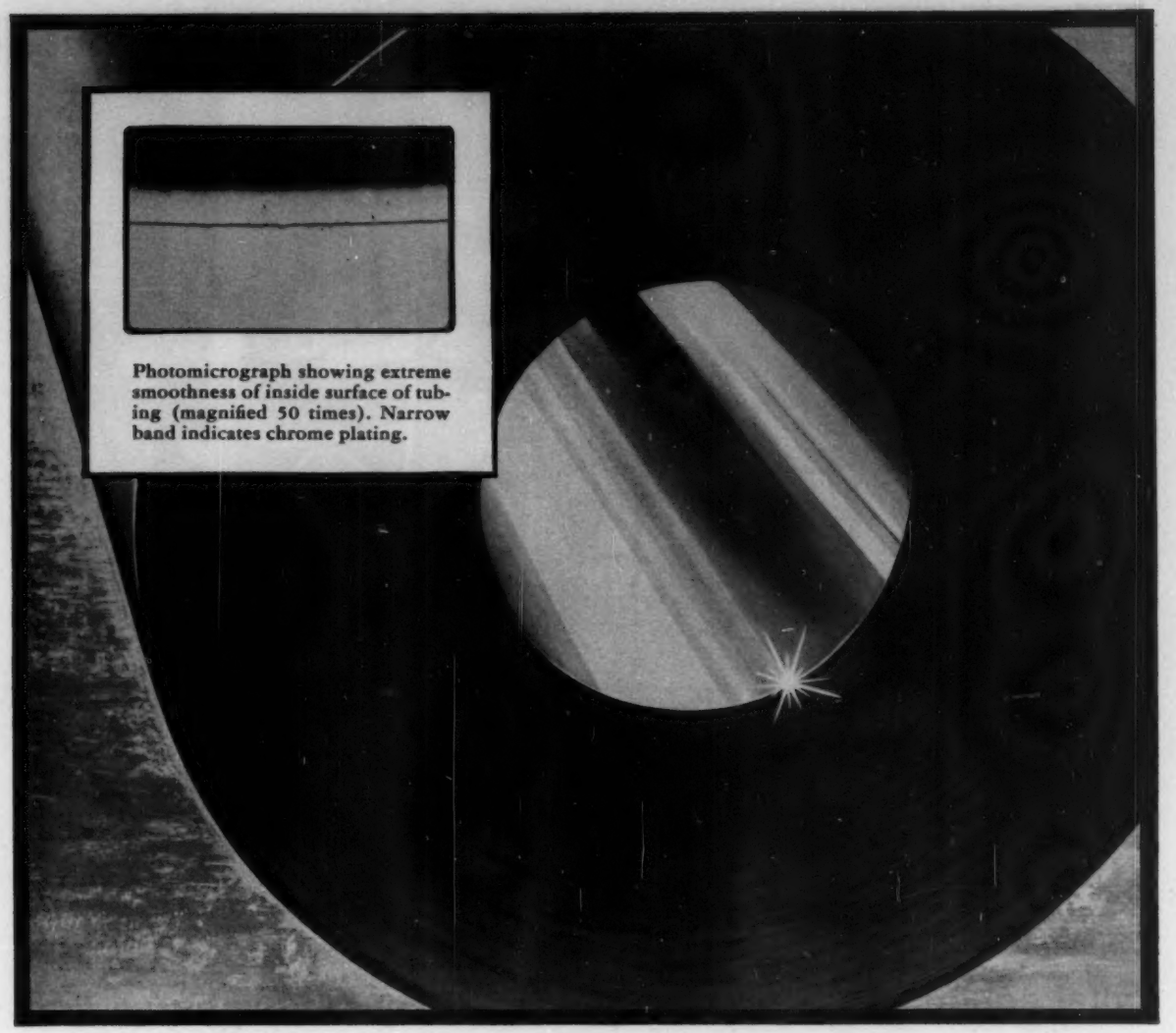
Find out more about this newest of fire protection ideas, and about the application of L. W. Blazecrete throughout the petroleum industry. Write to Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.



Gunned in place or slap troweled L. W. Blazecrete is the ideal material for refractory linings. It gives you an unusually strong, dense and homogeneous lining . . . ready for use within 24 hours.

JOHNS-MANVILLE

JOHNS-MANVILLE PRODUCTS



Photomicrograph showing extreme smoothness of inside surface of tubing (magnified 50 times). Narrow band indicates chrome plating.

How to beat fatigue

caused by pulsating pressures up to 50,000 psi

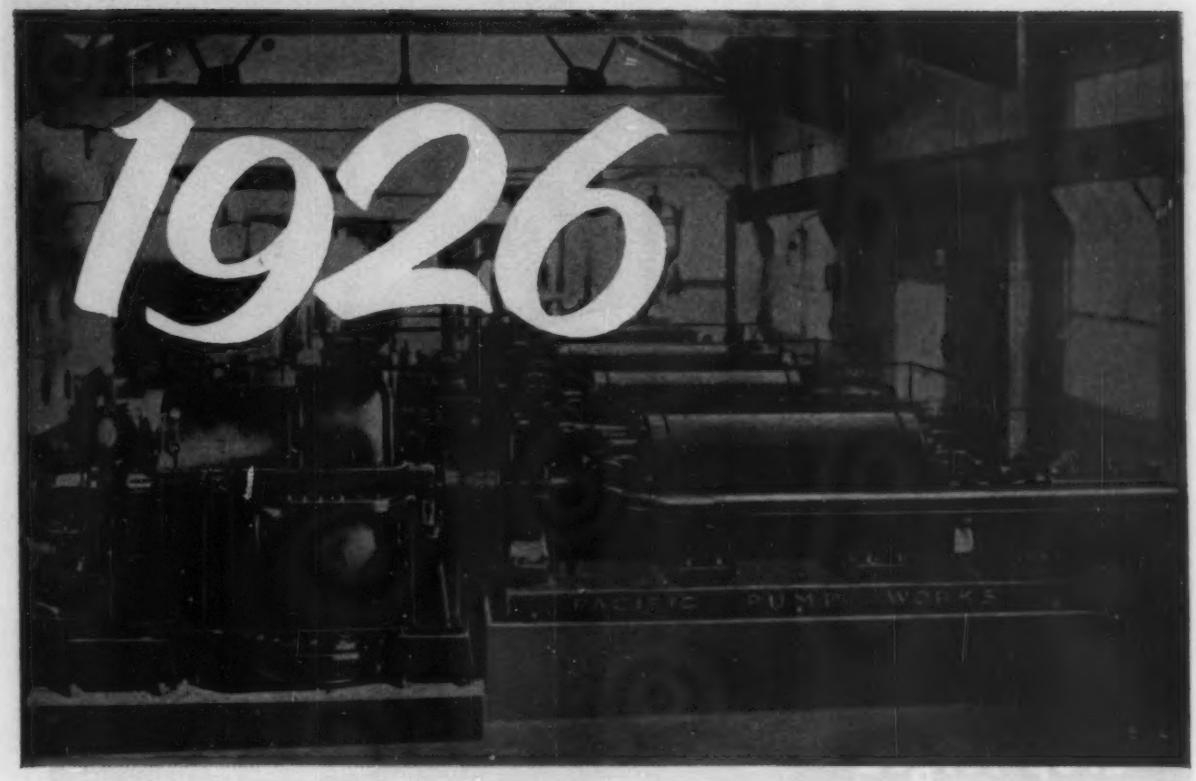
PROBLEM: Manufacturers of polyethylene plastic were plagued by *costly* fatigue failures in the heavy wall, high pressure steel tubing they were using. *Result:* Costly, frequent replacements with attendant production and time losses.

CAUSE: The tubing's inside surface had slight, almost invisible imperfections which gave the pulsating pressures—varying between 35,000 and 50,000 psi—a toe hold for failures to start.

SOLUTION: Timken Company metallurgists recommended a specific low-alloy steel tubing that could be produced with a glossy-smooth interior surface. They used specially developed Timken Company processing techniques, based on more than 40 years of experience with all types of high pressure steel applications. Result—another special steel problem solved.

WHATEVER your special steel problem, it will pay you to use the experience of the experts—metallurgists of the Timken Company. Give us a call the next time you need help. The Timken Roller Bearing Company, Steel & Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO". *Makers of Tapered Roller Bearings, Fine Alloy Steels and Removable Rock Bits.*

TIMKEN® *Fine Alloy* STEEL



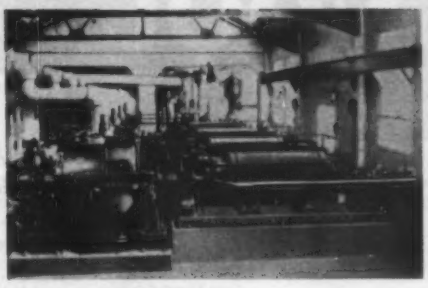
PACIFIC PUMPS

first "FIRST"

The centrifugal pumps designed and built for Pan American Oil Company's new high-pressure cracking process in 1926 was one of the most significant engineering achievements of the Twenties in the refinery processing field. The first of many Pacific Pumps' "FIRSTS", this particular pump was the forerunner of today's greatly improved Pacific centrifugal process pump line. Over the years Pacific has built and installed thousands of vertical and horizontal centrifugal pumps for extreme pressures and temperatures demanded by the petroleum, chemical, petro-chemical and allied industries. In addition, Pacific designs and manufactures boiler feed pumps for the power industry, steam turbo-pumps for the marine and power generation fields, and plunger pumps for oil-well service.

This first Pacific advertisement appeared in several petroleum publications early in 1927

2000 POUNDS PRESSURE WITH CENTRIFUGAL PUMPS



View of recent installation of four "PACIFIC" Multi-stage Pumps at Pan American Petroleum Company Refinery, Los Angeles. Each Pump delivers a capacity of 400 Gallons Per Minute of Oil against a pressure of 2000 pounds. Pumps are driven by 750 H. P. Steam Turbines. Each Pump weighs nine tons and was required to pass a hydrostatic test of 5000 pounds pressure.

We are prepared to make prompt shipment of Booster Pumps for Pipe Line or High Pressure service. Special Pumps designed for unusual conditions.

PACIFIC PUMP WORKS
350 Bicket Street Huntington Park Los Angeles, Cal.

Write for **Bulletin 1C**

PACIFIC

Offices in all Principal Cities

PACIFIC PUMPS
Inc... A Division of Dresser Industries, Inc.
HUNTINGTON PARK, CALIFORNIA

IR-1

For more data on advertised products, use Readers' Service Cards, last page.

STRONGER and SAFER for every high pressure pipeline duty...

...because they are drop forged by.

Vogt

Constantly imitated but never duplicated, Vogt forged steel fittings and flanges have unmatched strength and toughness for your most severe pipeline duties. Laboratory controlled materials and Vogt's special forging techniques assure products which are always uniform in structure, fine grained, and free from porosity. Thereby the shocks and stresses imposed by high pressures and high temperatures are easily withstood, and with stubborn resistance to erosion and corrosion. Consult Catalog F-10 for our complete line of fittings and flanges.

For a copy of Vogt Catalog F-10 address Dept. 24A-FPR.

HENRY VOGT MACHINE CO., P.O. BOX 1918, LOUISVILLE 1, KENTUCKY

SALES OFFICES: New York, Chicago, Cleveland, Dallas, Camden, N. J., St. Louis, Charleston, W. Va., Cincinnati

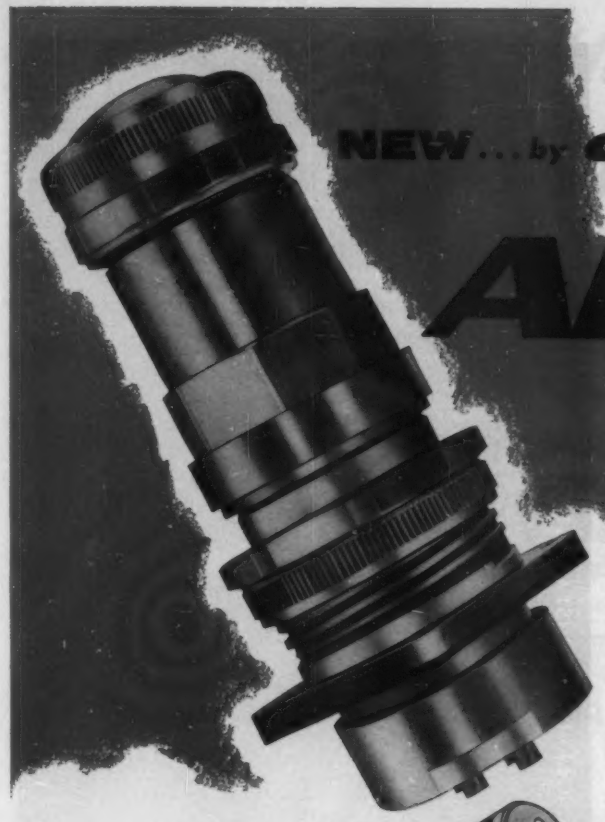
OTHER VOGT PRODUCTS

Forged Steel Valves — Petroleum Refinery and Chemical Plant Equipment — Steam Generators — Heat Exchangers — Ice Making and Refrigerating Equipment.

Vogt

DROP FORGED STEEL

Fittings and Flanges



NEW... by CROUSE/HINDS

ARK-trol®

ELECTRICAL CONNECTORS

• Foolproof polarization • Errorless assembly • Maximum interchangeability • Environmental: Exceed rigid military and industrial requirements for resistance to corrosion, chemicals, high and low temperatures, pressure, shock, vibration, dust, humidity, moisture, and leakage of air.

POSITIVE POLARIZATION

Completely foolproof: plug can be mated only with proper receptacle, and in only one way . . . the *right* way. Unsymmetrical contact arrangements preclude improper mating of contacts, or mating of unmatched contact configurations.

FAST, EASY, ERROR-FREE ASSEMBLY

Polarization keyways and unsymmetrical contact arrangement in insert assemblies make improper assembly of parts impossible. One-piece 'snap-in' connectors. Soldering is done outside... *before* insertion of contacts.

SEALED AGAINST ENVIRONMENTAL FACTORS

'Stack' assembly includes silicone rubber wafer for impenetrable seal against water, vapors, dust, gas. Basic shells, other metal parts are high-strength extrusions of aluminum alloy, anodized for corrosion, abrasion resistance: 1800 volts are required to penetrate this coating.

MAXIMUM INTERCHANGEABILITY

Components in each diameter are interchangeable and reversible, doubling scope of equipment. Male *and* female shells take either pin or socket inserts: both plug and receptacle may be used 'hot' or 'dead'. Pin and socket configurations available in wide range . . . specials supplied on request.

SHELL SIZES and ELECTRICAL RATINGS

Four shell sizes: from 1-1/16" to 2-9/16" diam. *Voltages:* Military Service Ratings: A, D, E, B, C and Instrument. NEC Rating: 600V. A.C. *Contact sizes:* #16 to #4/0 inclusive. Write for Bulletin 2711 containing complete descriptions, specifications and configuration patterns for both Type RPE and RPC *ARK-trol* Electrical Connectors.

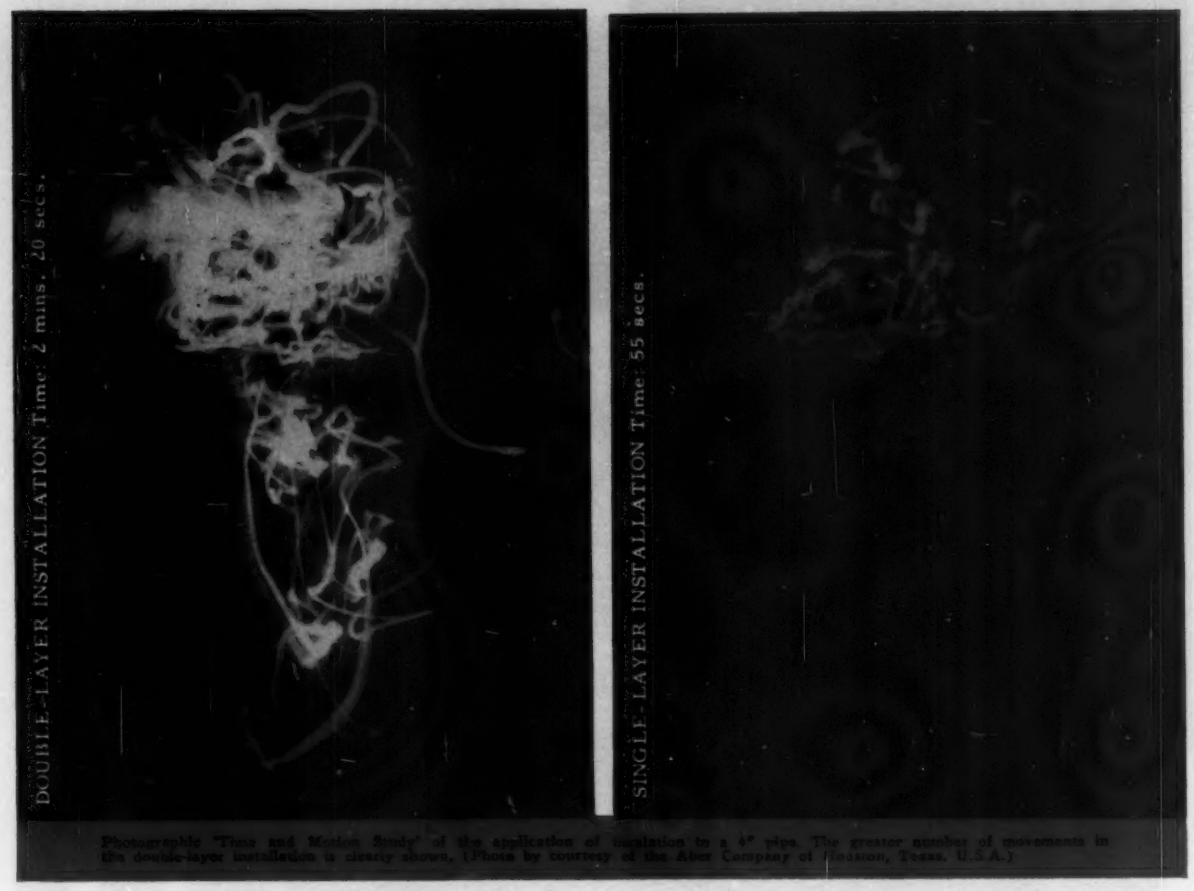
Available in two types:

TYPE **RPE** ENVIRONMENTAL
- Moisture Proof
- Shock Insulated
- Dust-Tight
- Corrosion Resistant
- Grounded & Non-Grounded

TYPE **RPC** CIRCUIT BREAKING
- All Features of RPE *Plus* . . .
- Circuit Breaking under full Rated Load

CROUSE HINDS SYRACUSE NEW YORK

OFFICES: Atlanta Baton Rouge Birmingham Boston Buffalo Charlotte Chicago Cincinnati Cleveland Corpus Christi Dallas Denver Detroit Houston Indianapolis Kansas City Los Angeles Milwaukee New Orleans New York Omaha Philadelphia Pittsburgh Portland, Ore. St. Louis St. Paul Salt Lake City San Francisco Seattle Tulsa Washington
RESIDENT REPRESENTATIVES: Albany Baltimore Reading, Pa. Richmond, Va.
CROUSE-HINDS COMPANY OF CANADA, LTD., TORONTO, ONT. CROUSE-HINDS INSTRUMENT COMPANY, INC., SILVER SPRING, MARYLAND



Photographic "Time and Motion Study" of the application of insulation to a 4" pipe. The greater number of movements in the double-layer installation is clearly shown. (Photos by courtesy of the Aber Company of Houston, Texas, U.S.A.)

One layer— Less work

CAPOSITE single-layer insulation

Insulation in a single layer! Caposite was developed by The Cape Asbestos Company to avoid the 'two-layer compromise' Caposite does it in one—saving considerably on installation time and costs. Caposite, the amosite asbestos insulation, is designed to withstand temperatures up to 1000° F. without loss of efficiency.

LOW JOINT LOSS

The fibrous edges of Caposite knit together at the joints giving a good heat seal and making staggered joints unnecessary.

EASY TO HANDLE

Its inherent strength makes it possible to handle Caposite in large sections for example at 2" thick for 30" n.p.s.—with very little damage and a further saving in installation costs.

CAPE

THE CAPE ASBESTOS COMPANY LIMITED

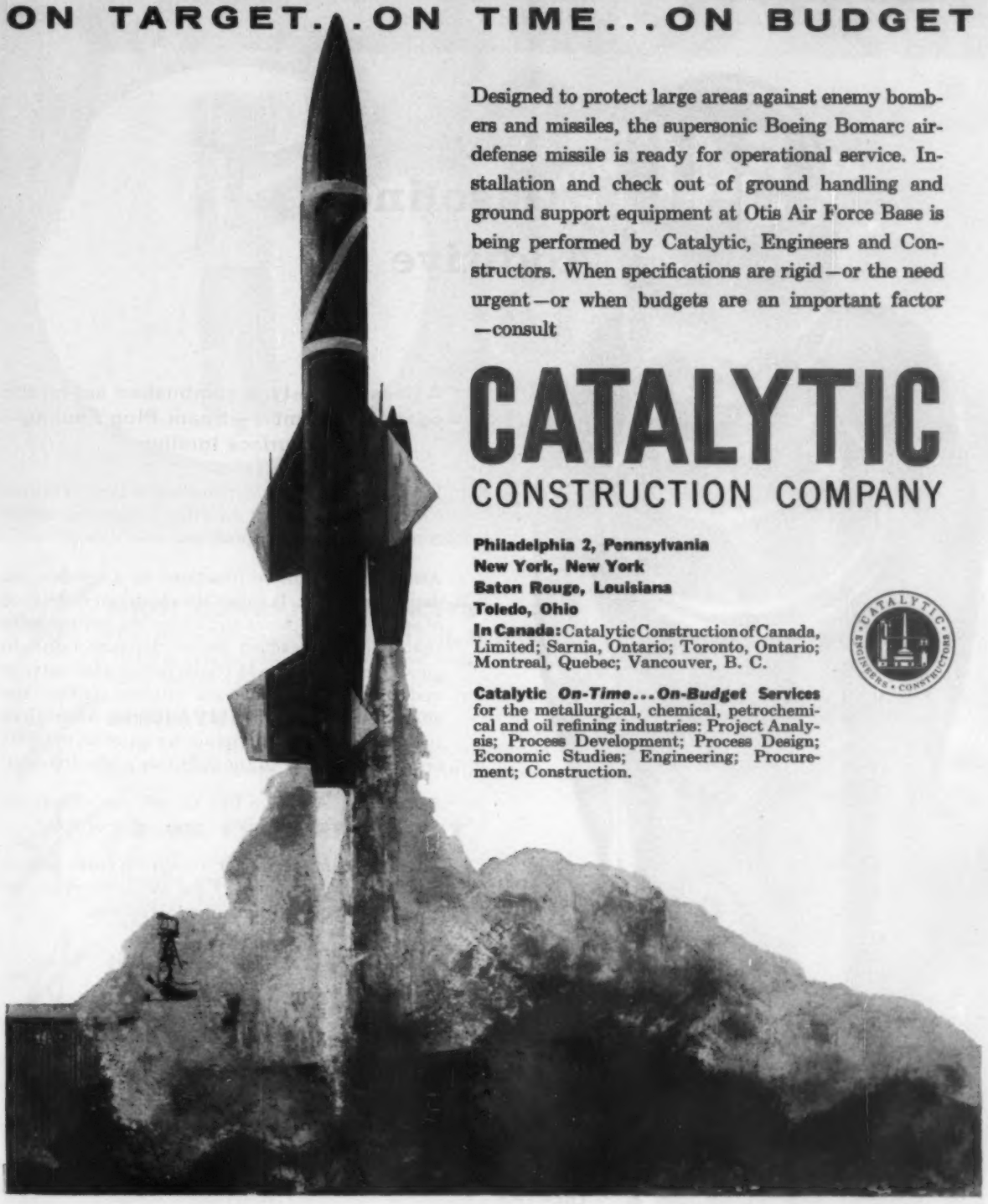
114 & 116 Park Street, London W. 1, Grosvenor 6022
Cables: Incorrupt London

Enquiries in Canada to: Cape Asbestos (Canada) Limited, 200 Bloor Street East, Toronto, Ontario.
U.S.A.: North American Asbestos Corporation, Board of Trade Building, Chicago 4, Illinois.

TA 2543

BOEING BOMARC MISSILE---

ON TARGET...ON TIME...ON BUDGET



Designed to protect large areas against enemy bombers and missiles, the supersonic Boeing Bomarc air-defense missile is ready for operational service. Installation and check out of ground handling and ground support equipment at Otis Air Force Base is being performed by Catalytic, Engineers and Constructors. When specifications are rigid—or the need urgent—or when budgets are an important factor—consult

CATALYTIC
CONSTRUCTION COMPANY

Philadelphia 2, Pennsylvania
New York, New York
Baton Rouge, Louisiana
Toledo, Ohio

In Canada: Catalytic Construction of Canada, Limited; Sarnia, Ontario; Toronto, Ontario; Montreal, Quebec; Vancouver, B. C.

Catalytic *On-Time...On-Budget* Services for the metallurgical, chemical, petrochemical and oil refining industries: Project Analysis; Process Development; Process Design; Economic Studies; Engineering; Procurement; Construction.

For more data on advertised products, use Readers' Service Cards, last page.

announcing

AMOCO

Gasoline Additive

A phosphorus-type combustion aid for the control of Rumble—Spark Plug Fouling—Surface Ignition

Here's a new Amoco phosphorus-type additive that can permit you to offer a gasoline which controls combustion problems.

AMOCO 541 Additive functions as a combustion deposit modifier. It raises the electrical resistance of spark plug deposits and raises the temperature that must be reached before deposits begin to glow. Bench tests, field trials, parking lot surveys and random passenger car studies confirm the effectiveness of AMOCO 541 Additive. More than two years use of the product by gasoline marketers further testify to the Additive's effectiveness.

AMOCO 541 Additive has no adverse effects on gasoline storage stability, gum, odor or color.

Literature and technical assistance from experienced additive specialists are available. Your inquiry will receive immediate attention.

AMOCO CHEMICALS

AMOCO CHEMICALS CORPORATION

910 South Michigan Avenue, Chicago 80, Illinois

This is all the room you need to weld with LINDE's "MIGHTY MIDGET"

. . . New Heliarc HW-20 Torch

HIGH CURRENT CAPACITY

Operates at 200 amperes *continuous* duty, AC or DC. Molded, totally closed water-cooling system eliminates any chance of leaks at torch head.

MINIATURE SIZE

9/16- by 2-5/16-in. torch head permits welding in hard-to-reach areas as small as 3 in. in diameter. Total torch length is under 7 inches.

3.3-OZ. FEATHERWEIGHT

Selected materials, such as glass fiber reinforced phenolic plastic, save weight without sacrificing strength. Torch (with short cap) weighs only 3.3 ounces.

HANDLES LIKE A PENCIL

Exceptional balance, light weight, small size, and super-flexible service lines make the HW-20 torch as easy to handle as a pencil.

For further information, call your local LINDE Office or LINDE Distributor . . . or write: Dept. PR-09 LINDE COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, New York.

SPECIFICATIONS

Capacity—
200 amp. AC or DC, continuous duty cycle;
225 amp. AC or DC, reduced duty cycle

Weight—
with short cap: 3.3 oz.*
with medium cap: 3.5 oz.
with long cap: 3.6 oz.

Length overall—6⅞ in.

Length of Torch Head—
with short cap: 2-19/64 in.*
with medium cap: 3-9/32 in.
with long cap: 7-5/16 in.

Maximum Handle Diameter—¾ in.

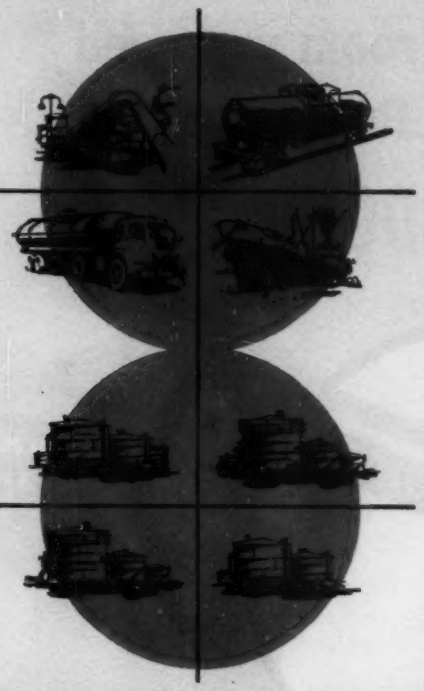
Maximum Head Diameter—9/16 in.

Service Lines—12½ or 25 ft.

*Torch is supplied with medium cap for 3-in. electrodes. Short cap for 2-in. electrodes and long cap for 7-in. electrodes are available as accessories.

Linde UNION CARBIDE

The terms "Heliarc," "Linde," and "Union Carbide" are registered trade marks of Union Carbide Corporation.



SHIP 'EM

or

STORE 'EM

NALCO-TREATED FUEL OILS STAY FRESH!

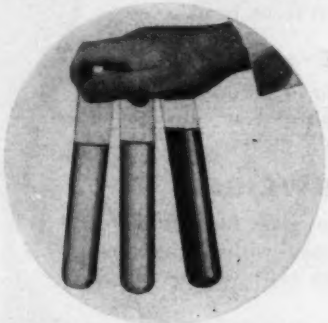
Get rid of the hurry-up-and-sell pressure caused by unstable fuel oils that darken and sludge up when stored or shipped any distance. New Nalco 303-AC is the fuel oil dispersant-stabilizer that gives you *best* control of sludging tendencies—keeps fuel oils refinery-fresh, bright, and sludge-free even when shipped thousands of miles and stored for months.

Ask for product information on this new chemical for distillate fuels. It is available promptly from your Nalco Representative, or from Nalco direct.

National Aluminate Corporation is now

NALCO CHEMICAL COMPANY • 6216 West 66th Place, Chicago 38, Illinois

Subsidiaries in England, Italy, Mexico, Spain, Venezuela and West Germany
In Canada—Alchem Limited, Burlington, Ontario



Fuel oil at *left* is fresh from refinery, bright and clear. *Center*, Nalco-treated oil is bright and sludge-free after four months. *Right*, untreated sample in four months time has darkened considerably, already begun to sludge.

Nalco®
PRODUCTS

SERVING THE PETROLEUM INDUSTRY THROUGH PRACTICAL APPLIED SCIENCE

Nalco CHEMICALS

MADE TO ORDER

In a variety of combinations, chemical plant and oil refinery equipment require alloy steels: Some components with stainless parts . . . some completely stainless . . . some with a number of other alloys, but all capable of specific customized functions.

Whatever your requirement for Specialty, Sun Ship is prepared to custom-construct pressure vessels, plate work, autoclaves and machinery . . . each to specifications and requirements . . . each made to order.

Sun

SHIPBUILDING & DRY DOCK COMPANY

ON THE DELAWARE • SINCE 1916 • CHESTER, PA.

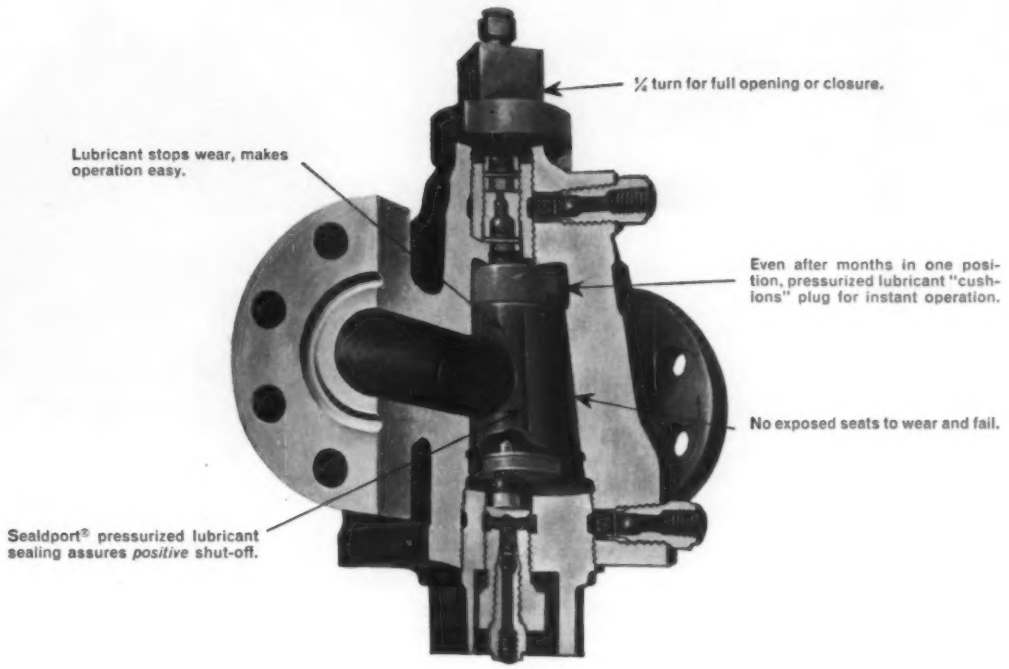
ROCKWELL- Nordstrom **VALVES**

Confidence

A parachute is worn with the hope that it will not be used, yet with the *confidence* that it will do the job if it's needed.

Some valves are like parachutes. On fire lines or emergency shut-offs, for example, they're the valves you never want to use. But they are the ones that must perform *perfectly* if the need arises. Most often you'll see Rockwell-Nordstrom lubricated plug valves in these "confidence" services because half a century of on-the-job proof has established one important fact: *they are valves you can depend on*. And it's this confidence on the tough services that has made them demanded so often on *every* service.

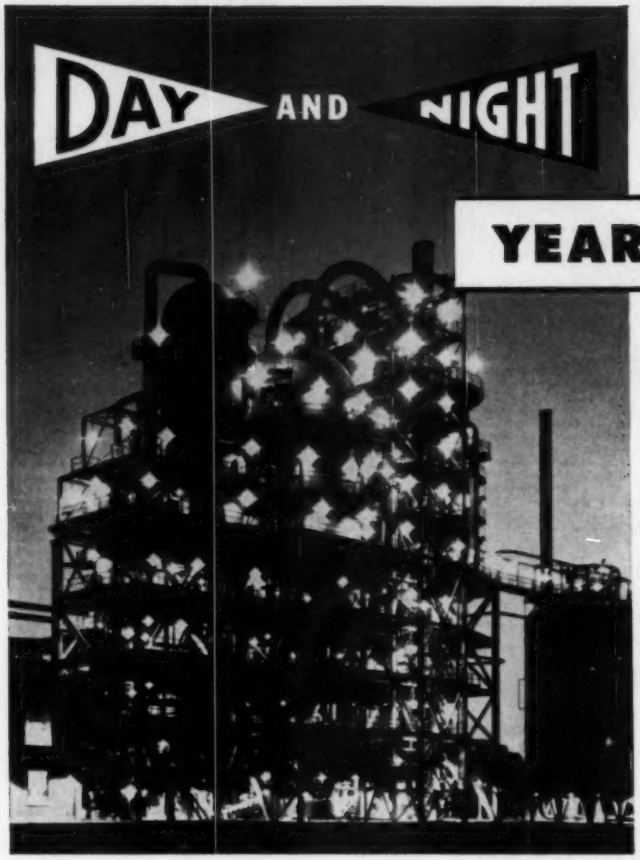
INSTANT, DEPENDABLE VALVE OPERATION


¼ turn for full opening or closure.
Lubricant stops wear, makes operation easy.
Even after months in one position, pressurized lubricant "cushions" plug for instant operation.
No exposed seats to wear and fail.
Sealdport® pressurized lubricant sealing assures *positive* shut-off.

Rockwell-Nordstrom is the original and world's most complete line of lubricated plug valves with sizes from ¾" to 36" and pressures to 15,000 lb. Available at leading oil field and industrial supply houses everywhere. For details, see your supplier or write: Rockwell Manufacturing Company, Pittsburgh 8, Pa. If you live outside the U. S. A., write: Rockwell International Division, Pittsburgh 8, Pa.

ROCKWELL-Nordstrom VALVES
another fine product by
ROCKWELL

®Reg. T.M. Rockwell Manufacturing Company



YEAR-IN, YEAR-OUT

always DEPENDABLE

LimiTorque VALVE CONTROLS

Round the clock, dependable service has been performed by LimiTorque in Refineries and High Pressure Oil and Gas Transmission Lines for a period of 27 years . . . in Canada, Alaska, Venezuela, the Middle East, Sumatra, Sahara, Mexico; all over Continental Europe, and of course, throughout the United States.

Faithful, Dependable Valve Operating Service is the big factor that has made LimiTorque famous—and it is the reason why LimiTorque is the most widely used Valve Operator in the World.

LimiTorque is available in numerous types and variations . . . all "custom built" to do the exact job you require . . . Speeds of operation can be varied over a wide range, even to the provision of two speeds in one direction of travel—and Electrical Control Equipment, such as reversing starters, relays, transformers, etc. may be included, to make a complete operating "package".

Regardless of whether valves are to be automatically operated indoors or outdoors—in sub-zero or elevated temperatures —under snowy, rainy, dusty, or bad fume conditions, there's an exact type and size of LimiTorque to meet your valve operating requirements.

Consult your Valve Manufacturer, or your nearest LimiTorque Sales Engineering Office . . . and remember, there are 27 years of continuous designing and manufacturing experience back of LimiTorque.

Send for Catalog L-550, and please use your Business Letterhead.

THERE IS NO SUBSTITUTE FOR —

LimiTorque®

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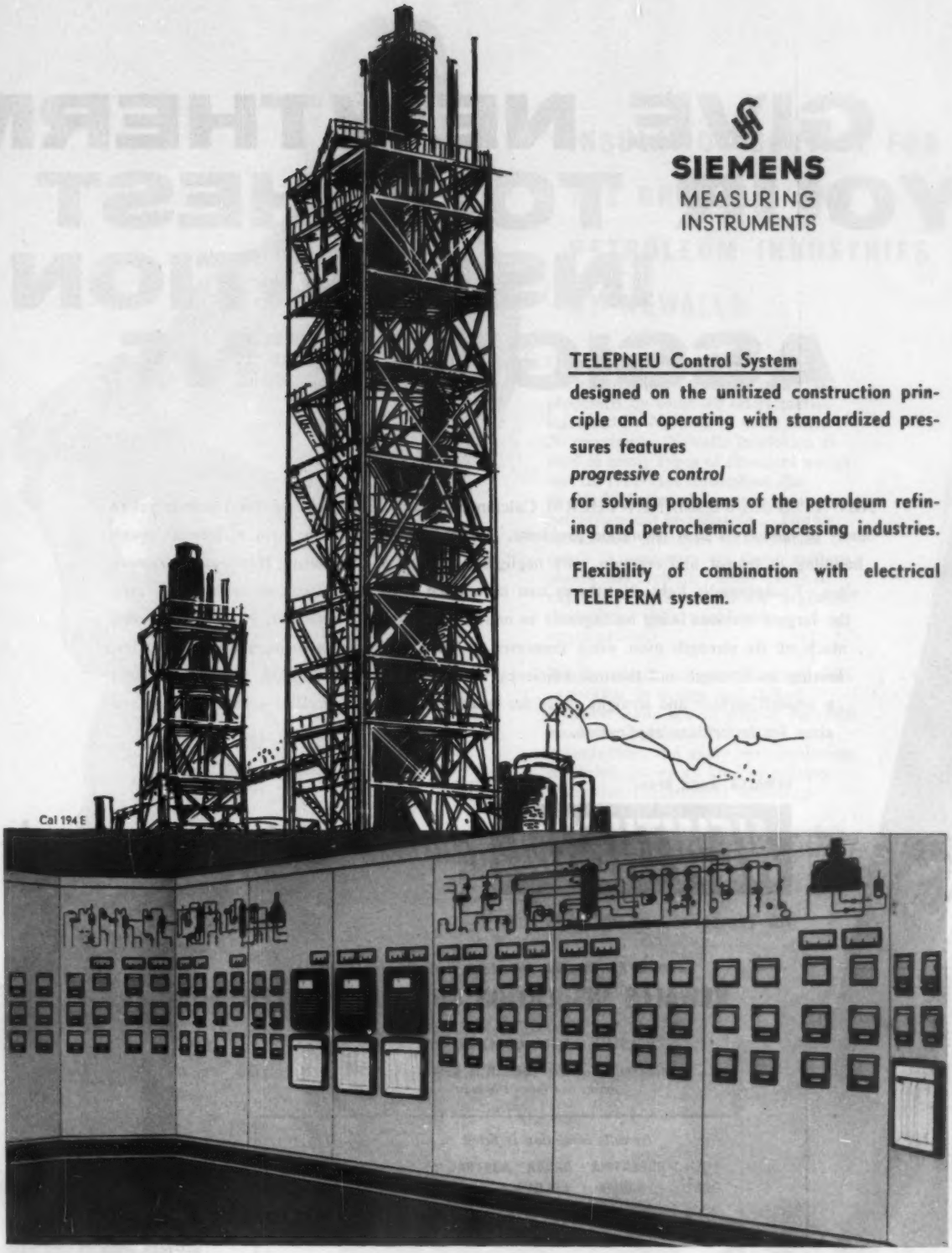
ERIE AVE. & G STREET, PHILADELPHIA 34, PENNA.

Offices in all Principal Cities

INDUSTRIAL GEARS & SPEED REDUCERS • LIMITORQUE VALVE CONTROLS • FLUID AGITATORS • FLEXIBLE COUPLINGS

Limitorque Corporation • Philadelphia



SIEMENS
MEASURING
INSTRUMENTS

TELEPNEU Control System

designed on the unitized construction principle and operating with standardized pressures features
progressive control
for solving problems of the petroleum refining and petrochemical processing industries.

Flexibility of combination with electrical TELEPERM system.

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For more data on advertised products, use Readers' Service Cards, last page.

GIVE NEWTHERM YOUR TOUGHEST INSULATION ASSIGNMENT

NEWALLS (Reg'd Brand) NEWTHERM Calcium Silicate insulation is the finest answer yet to many of industry's heat insulation problems. Strong and rigid, Newtherm withstands rough handling in transit and erection, with negligible breakages even during transport to remote sites. Exceptionally light, Newtherm can be applied in difficult situations with ease—even the largest sections being manageable in one hand. Moisture resistant, Newtherm retains much of its strength even when immersed in water, does not deform, and quickly dries, leaving its strength and thermal efficiency unimpaired. Easily applied, Newtherm offers a smooth surface and straight edges for speedy fitting, and is available in many standard sizes for immediate application.

NEWALLS (Reg'd Brand)

NEWTHERM *calcium silicate insulation!*

for temperatures up to 1400°F.

NEWTHERM Calcium Silicate is manufactured solely by

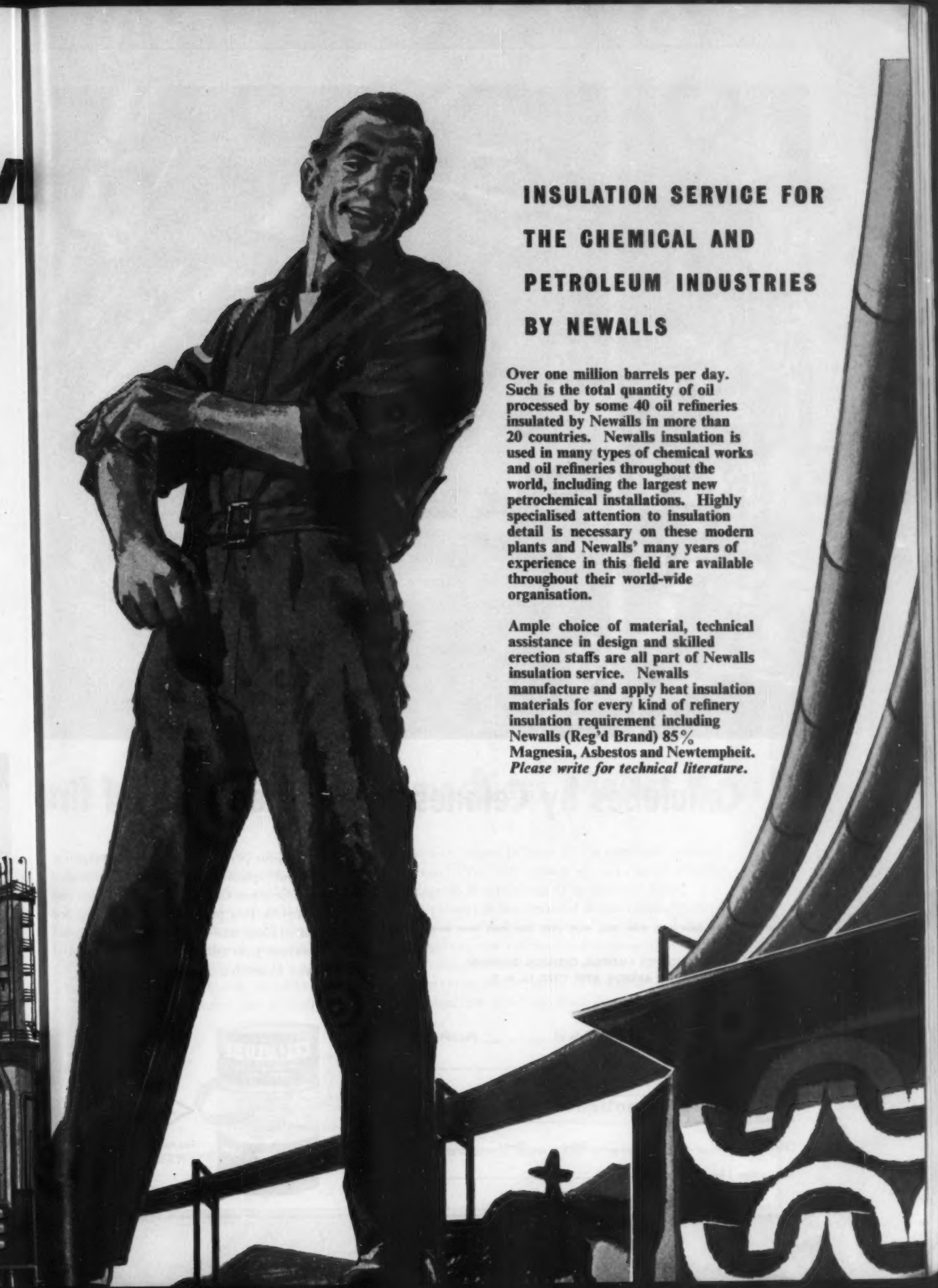
NEWALLS INSULATION COMPANY LIMITED

Head Office & Export Dept:
WASHINGTON, Co. DURHAM, ENGLAND

A member of the **TURNER & NEWALL ORGANISATION**
Agents and Vendors in most markets abroad

Newalls insulation is fitted on refineries in

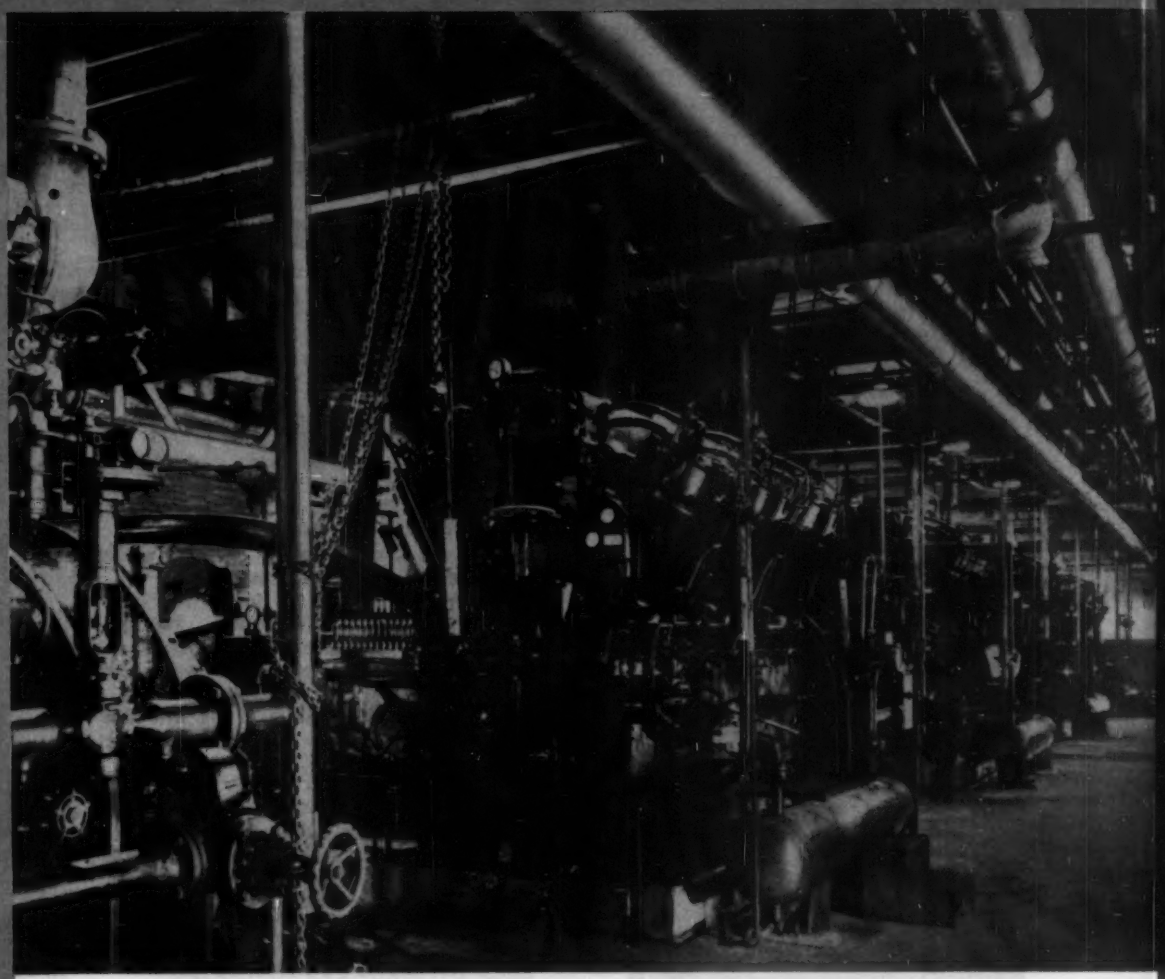
ADEN · ARGENTINA · ARUBA · AUSTRALIA · BAHRAIN · BELGIUM
BRAZIL · BURMA · COLOMBIA · CUBA · FRANCE · HOLLAND
INDIA · IRAN · IRAQ · ISRAEL · KUWAIT · PERU · ROUMANIA
SAUDI ARABIA · TRINIDAD · UNITED KINGDOM · VENEZUELA



INSULATION SERVICE FOR THE CHEMICAL AND PETROLEUM INDUSTRIES BY NEWALLS

Over one million barrels per day. Such is the total quantity of oil processed by some 40 oil refineries insulated by Newalls in more than 20 countries. Newalls insulation is used in many types of chemical works and oil refineries throughout the world, including the largest new petrochemical installations. Highly specialised attention to insulation detail is necessary on these modern plants and Newalls' many years of experience in this field are available throughout their world-wide organisation.

Ample choice of material, technical assistance in design and skilled erection staffs are all part of Newalls insulation service. Newalls manufacture and apply heat insulation materials for every kind of refinery insulation requirement including Newalls (Reg'd Brand) 85% Magnesia, Asbestos and Newtempheit. ***Please write for technical literature.***



Cellulubes by Celanese minimize threat of fire and

Protection of your personnel, plant and equipment against fire and explosion is a vital need. Cellulubes made by the Celanese Corporation of America can help you provide this protection. They resist the propagation of flame under conditions which could result in serious fires with other lubricants. And they give you so much more!

FM
Factory Mutual-Approved
(Cellulubes 150 and 220)

CELANESE CORPORATION OF AMERICA, CHEMICAL DIVISION
DEPT. 574-S, 180 MADISON AVENUE, NEW YORK 16, N. Y.

Please send me:

☐ Technical bulletin ☐ Sample of_____viscosity.

Name_____ Title_____

Company_____

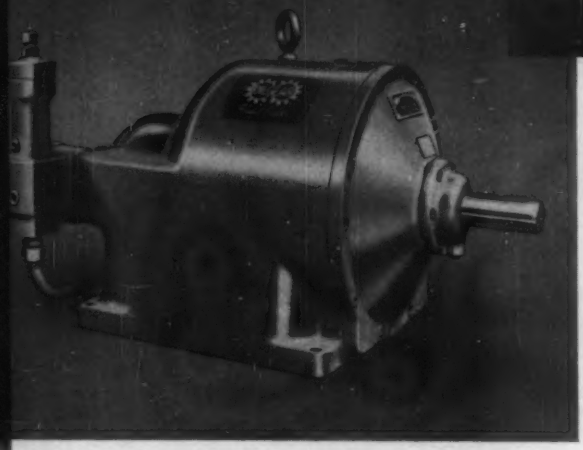
Address_____

City_____ Zone_____ State_____

Application I have in mind_____

CYLINDER WEAR PROVED NEGLIGIBLE when fire-resistant Cellulubes were used to lubricate four Cooper-Bessemer air compressors, as two years' testing showed. Moreover, there were no pressure surges or evidence of fire in the air accumulator. Deposits normally found in compressor auxiliaries and valves were reduced or eliminated thanks to the detergent action of Cellulubes. Conventional lubricators could be used to pump the Cellulubes.

SAFETY, EFFICIENCY, COST SAVINGS are the advantages of Cellulubes discovered by Trunkline Gas Company Texas, after using these lubricant fluids for three years in their air compressors: Cellulubes eliminate risk to personnel from fire, explosion, fragmentation. Cellulubes do not get dirty or burn away by friction or compression. Cellulubes save on replacement costs, downtime, and maintenance. Cellulubes keep machinery smooth-running and clean.



USED FOR YEARS under rigorous conditions in pumps made by the Oilgear Company of Milwaukee, Wisconsin, Cellulubes provided superior protection against excessive wear. Cellulubes, which are phosphate ester synthetic fluids, can be employed in pumps at higher temperatures than fire-resistant fluids which contain water. They are suitable for use in all types of hydraulic pumps being used today, including vane, piston and gear pumps.

ire and explosion...protect machines against wear

For example, Cellulubes give overall wear protection comparable to that of premium petroleum oils. They present no foaming problem and have no additives which might deposit in the system. In fact, these synthetic lubricants and hydraulic fluids have a cleansing action inside machinery. Their vapor pressure is extremely low; this means that fluid losses are negligible even under severe operating conditions. Cellulubes are available in six viscosity ranges to meet all the standard needs of industry. Viscosity ratings do not change despite the toughest conditions of mechanical shear.

A pioneer in fire-resistant fluids, Celanese offers you years of field experience and research background to serve your needs. For more information on Cellulubes, mail the coupon to us today.

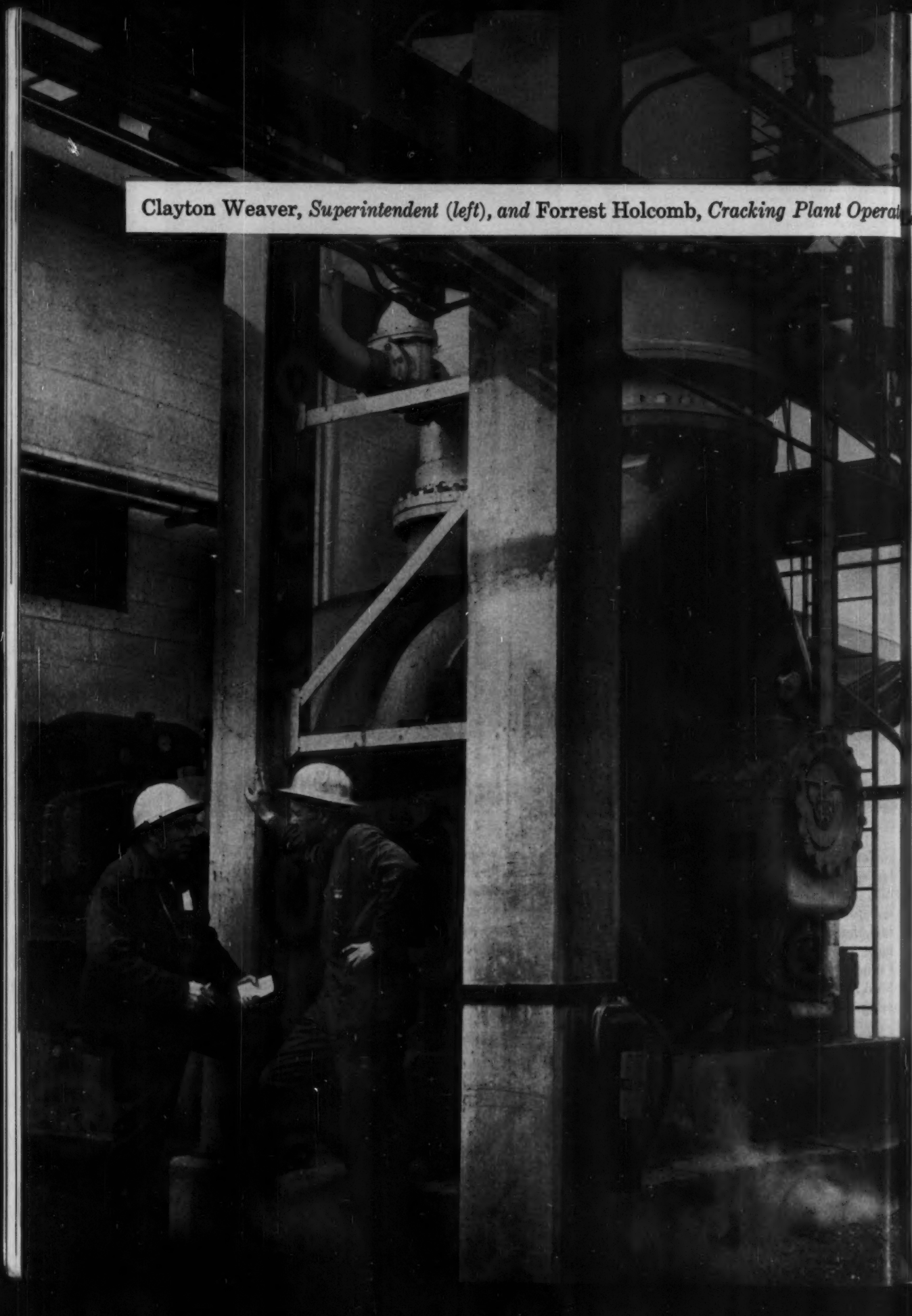
Celanese Corporation of America, Chemical Division, 180 Madison Ave., New York 16, N. Y.

Celanese® Cellulube®

Cellulubes... Celanese CHEMICALS **fire-resistant functional fluids**

In Canada: Canadian Chemical Company Limited, 2035 Guy St., Montreal, Toronto, Vancouver • Export Sales: Amcel Co., Inc., and Pan Amcel Co. Inc., 180 Madison Ave., New York 16

CELANESE CELLULUBES



Clayton Weaver, *Superintendent (left), and* Forrest Holcomb, *Cracking Plant Operat*eonard

Operat *eonard Refineries, discuss function of air supply in catalytic cracking and...*

How Cooper-Bessemer centrifugal compressor supplies big-volume air 'round-the-clock

As "Doc" Weaver, Superintendent of Leonard Refineries, Inc., Alma, Michigan explains . . ."Big centrifugals are the answer, of course, where modern processing calls for an extremely dependable air or gas supply at high volume and relatively low pressure. For example, our catalytic cracking requires this kind of air supply for burning coke off the catalyst. Our Cooper-Bessemer Type RS Centrifugal Compressor delivers 31,500 cfm at 30 psi discharge pressure. And, it produces this flow on a continuous, 24-hour basis. We are mighty pleased with its reliable performance."

Find out how Cooper-Bessemer Centrifugal Compressors can help solve *your* processing, air supply or compression problems for optimum economy. There is a type and size of unit for every need. Call our nearest office for complete details.

BRANCH OFFICES: Grove City • New York • Washington • Gloucester • Chicago Minneapolis • St. Louis • Kansas City • Tulsa • New Orleans • Shreveport • Houston Greggton • Dallas • Odessa • Pampa • Casper • Seattle • San Francisco • Los Angeles

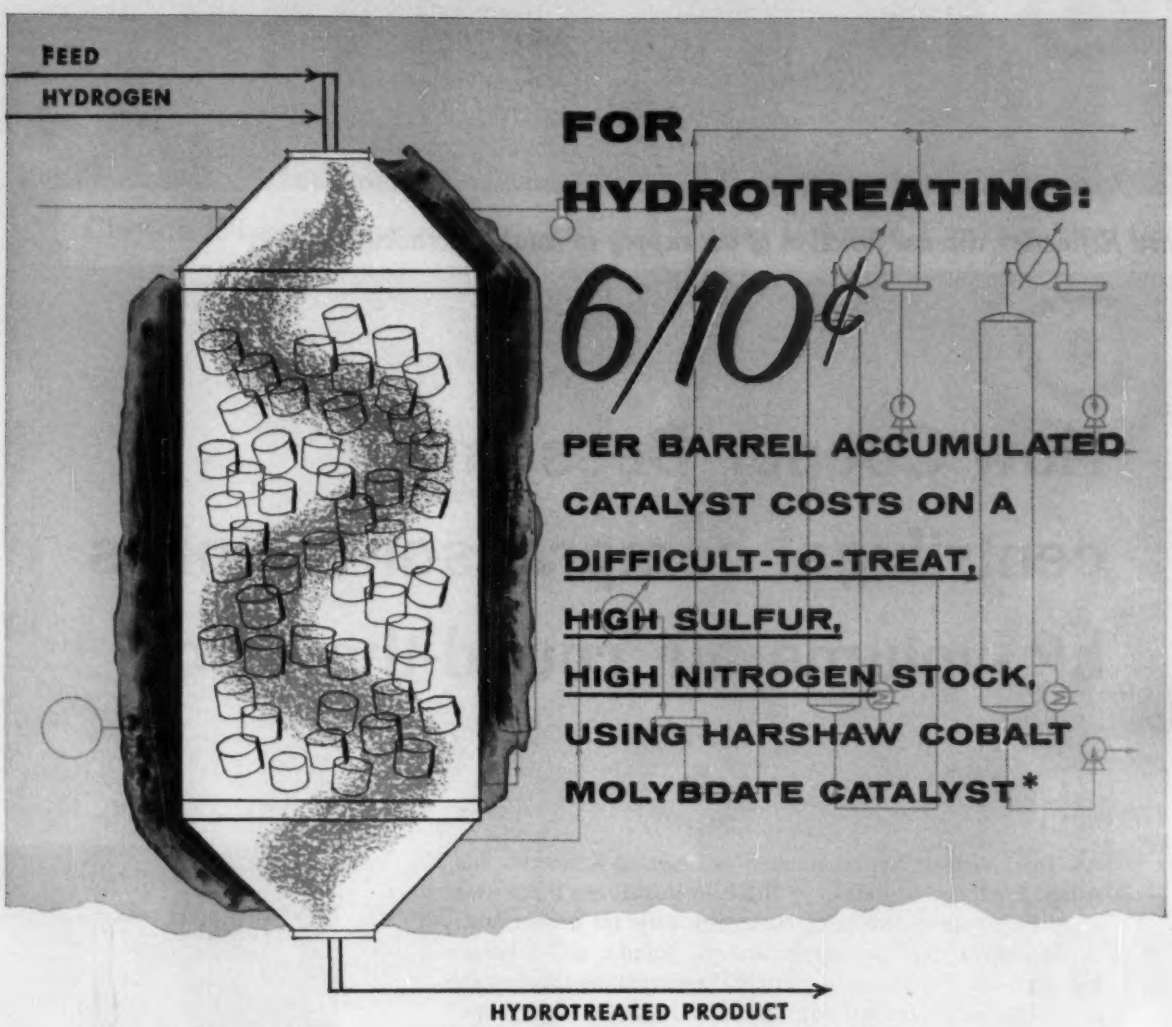
SUBSIDIARIES:
Copper-Bessemer of Canada, Ltd. . . . Edmonton • Calgary • Toronto • Halifax
C-B Southern, Inc. . . . Houston
Cooper-Bessemer International Corporation . . . New York • Caracas • Mexico City

Cooper-Bessemer Centrifugal Compressors are available in multi-stage type for volumes up to 100,000 cfm . . . in barrel type for air or gas supply at pressures up to 5000 psi. Also in pipeline boosters in ratings up to 20,000 bhp. Shown above: Cooper-Bessemer barrel type centrifugal compressor.

Cooper Bessemer

GENERAL OFFICES: MOUNT VERNON, OHIO

ENGINES: GAS • DIESEL • GAS-DIESEL
COMPRESSORS: RECIPROCATING AND CENTRIFUGAL
ENGINE OR MOTOR DRIVEN



Consistently low catalyst costs for hydrotreating, using Harshaw Cobalt Molybdate Catalyst, are possible because the inherent ruggedness and high thermal stability of our catalyst permits repeated regenerations while maintaining full activity—in one instance *223* regeneration cycles without loss in activity.

This versatile Harshaw catalyst performs efficiently over a wide range of feedstocks—from low boiling naphthas to heavy coker distillates. In all applications, the long life of our catalyst reflects reduced per-barrel costs.

For further information contact the Harshaw Branch nearest you. Our representative will be happy to discuss with you the application of Harshaw Cobalt Molybdate Catalyst to your operation.

*Based on an actual customer experience to date in a specific unit still operating. Its continuing operation will further reduce the 6/10¢ per barrel cost.

HARSHAW

THE HARSHAW CHEMICAL CO.

1945 E. 97th STREET • CLEVELAND 6, OHIO

CHICAGO
CINCINNATI
CLEVELAND
DETROIT
HASTINGS-ON-HUDSON
HOUSTON
LOS ANGELES
PHILADELPHIA
PITTSBURGH

For more data on advertised products, use Readers' Service Cards, last page.

CB&I CRAFTSMANSHIP IN STEEL

...the product of Engineering with Imagination

This unique vacuum tower was fabricated and erected by CB&I to meet an exacting set of performance requirements at the El Paso refinery of Standard Oil of Texas:

FEED: 13,000 barrels per day, reduced crude

NOMINAL PRESSURE: 2 pounds per square inch, absolute

OPERATING TEMP: 750 degrees Fahrenheit (approx.)

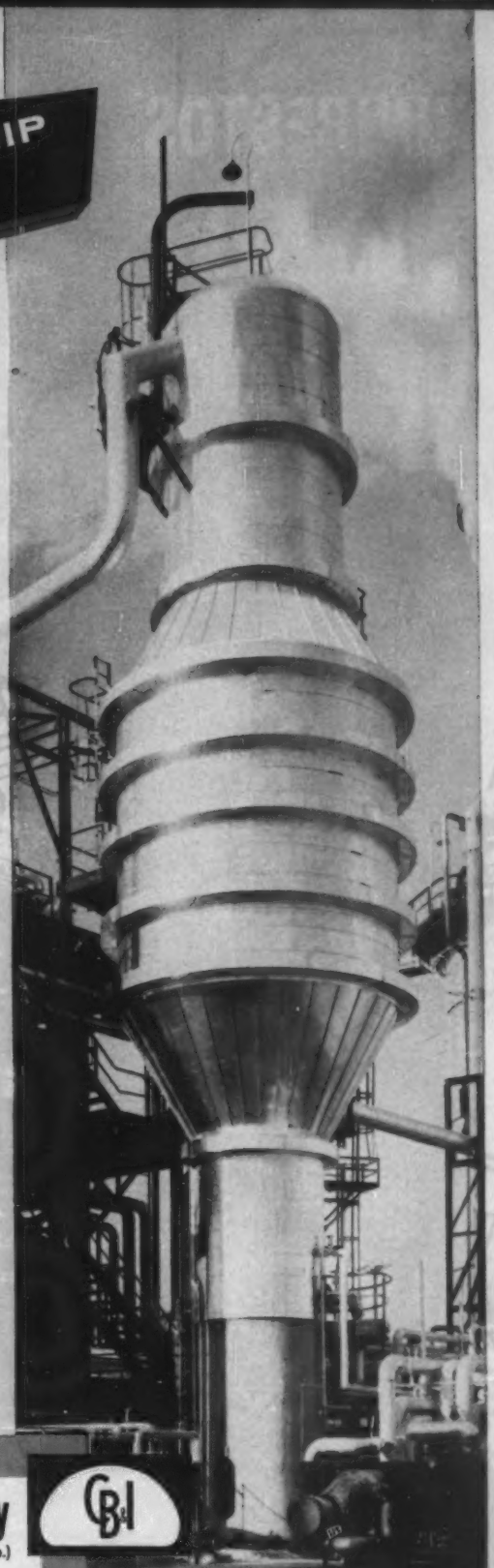
HEIGHT: 87 feet

DIAMETER: Varies from 8 to 18 feet

What is CB&I *Craftsmanship in Steel?* This unusual structure is a good example. It is engineering tempered with imagination. It is close attention to metallurgical control and structural detail. It is careful customizing of structure to process. Most important, it is *experienced coordination* through *all* phases of engineering, fabrication and erection.

These *coordinated services* are the reason why leading refiners rely again and again on CB&I for their critical tanks, towers and processing structures. For more information, write your nearest CB&I office, today. Ask for the brochure: *CB&I Craftsmanship in Steel.*

CB&I-built vacuum tower designed for reduced crude feed of 13,000 bpd. CB&I also built a reactor and regenerator, furnished through Fluor Corporation, Limited, for Standard Oil of Texas.

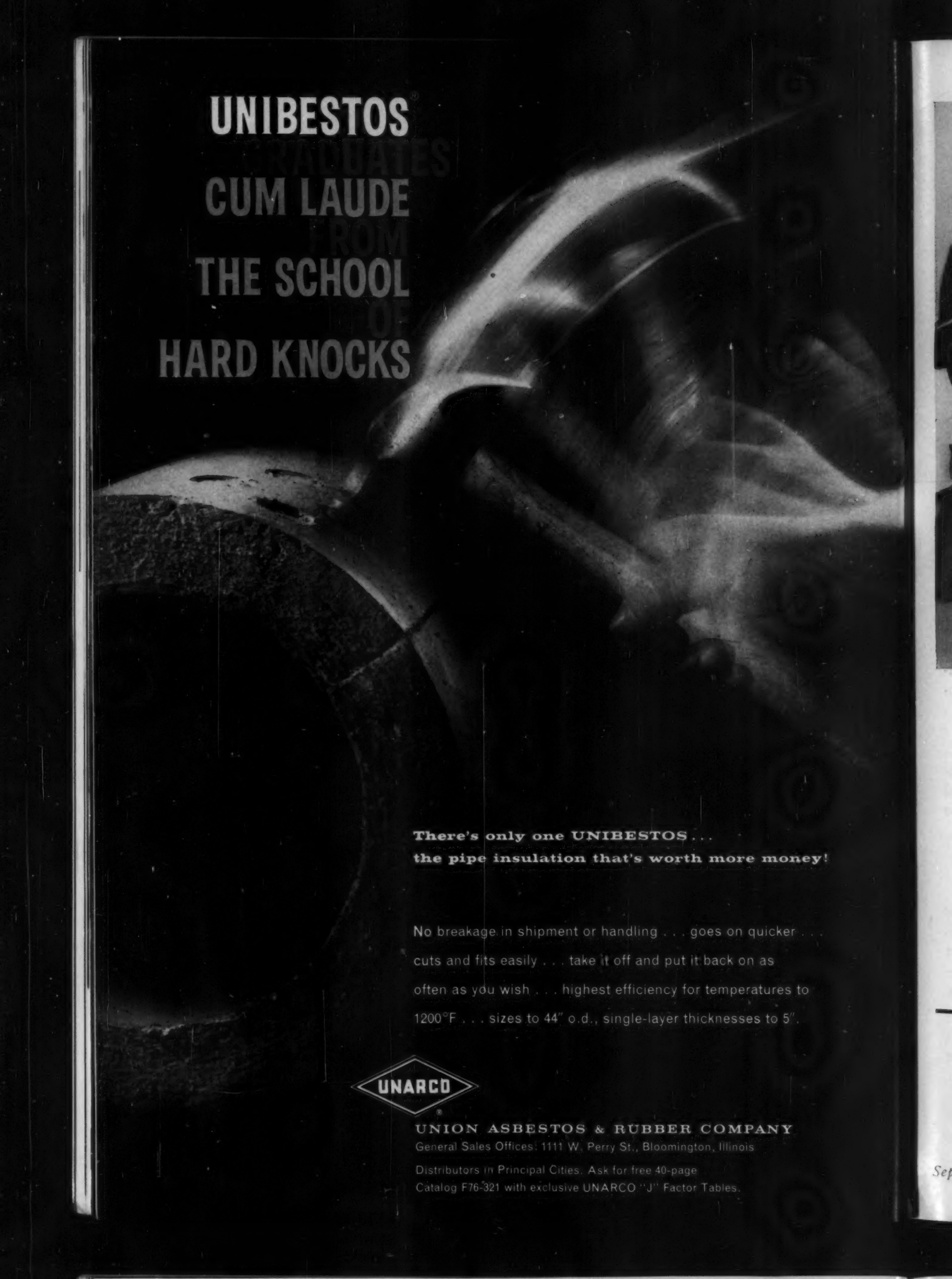


Chicago Bridge & Iron Company

Atlanta • Birmingham • Boston • Chicago • Cleveland • Detroit • Houston • Kansas City (Mo.)
New Orleans • New York • Philadelphia • Pittsburgh • Salt Lake City
San Francisco • Seattle • South Pasadena • Tulsa
Plants in Birmingham • Chicago • Salt Lake City • Greenville, Pa. • New Castle, Delaware
SUBSIDIARIES:
Horton Steel Works Limited, Toronto; Chicago Bridge & Iron Company Ltd., Caracas; Chicago Bridge Limited, London; Chicago Bridge Construcoes Ltda., Rio de Janeiro
REPRESENTATIVES AND LICENSEES:
Australia, Cuba, England, France, Germany, Italy, Japan, Netherlands, Scotland

CB&I ENGINEERS
CB&I FABRICATES
CB&I ERECTS

P84CB



There's only one UNIBESTOS . . .
the pipe insulation that's worth more money!

No breakage in shipment or handling . . . goes on quicker . . . cuts and fits easily . . . take it off and put it back on as often as you wish . . . highest efficiency for temperatures to 1200°F . . . sizes to 44" o.d., single-layer thicknesses to 5".

UNARCO

UNION ASBESTOS & RUBBER COMPANY
General Sales Offices: 1111 W. Perry St., Bloomington, Illinois

Distributors in Principal Cities. Ask for free 40-page Catalog F76-321 with exclusive UNARCO "J" Factor Tables.

SELECTIVE! EASY! FAST!

that's petroleum refining with QO® FURFURAL

SELECTIVE

QO FURFURAL is a polar molecule and gives *sharp* separation between mixtures of products present in lube stocks.

EASY

- QO FURFURAL is so stable, over 99.95% can be recovered easily by a simple system.
- QO FURFURAL is easy to store and easy to handle—even in icy weather.
- QO FURFURAL is easy to obtain in large quantities all year 'round.

FAST

QO FURFURAL's high specific gravity permits *rapid* phase separation. And faster refining means more economical refining.

Leading petroleum companies have found that solvent refining with QO Furfural is an efficient and economical operation. Get the details on QO Furfural by writing today for Bulletin 203-A.

The Quaker Oats Company

CHEMICALS DIVISION

The Quaker Oats Company — CHEMICALS DIVISION — QO CHEMICALS

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In Australia:
Swift & Company, Ltd., Sydney

In Japan:
F. Kanematsu & Company, Ltd., Tokyo

For more data on advertised products, use Readers' Service Cards, last page.

What every chemical processor should know ...about NORTON

You can meet a *wide* variety of chemical and petrochemical processing requirements efficiently and economically with NORTON Products. They're more than just outstanding refractory materials. In addition, they provide versatile combinations of chemical, physical, and electrical properties that make them valuable aids at many critical stages of production. Find out how these advanced materials from the NORTON electric furnaces can help *your* operations by substantially improving process and product . . . sharply reducing operating costs. If you wish, the NORTON Man will be happy to discuss processing problems with you at any time. Backed by years of experience in the field, he's well qualified to help. Write NORTON COMPANY, Refractories Division, 468 New Bond Street, Worcester 6, Massachusetts.

FOR CATALYSIS

A full line of catalyst carriers to meet the requirements of a wide range of feedstocks and thermal conditions. For coated or impregnated use. Size, weight, porosity, pore diameter, and purity held to close tolerances to assure precise duplication of results.

SHAPES	MATERIALS	POROSITY
Spheres	Alumina	from 10% to 50%
Rings	Silicon Carbide	
Pellets	Fused Magnesia	Surface Area
Granules	Zirconia	
Powders	Silica, Zircon	From less than 1
	Magnesia-Alumina	to 70 M^2/gram*
	Spinel, etc.	

Bulletin No. 7 gives full details. *BET Method

FOR FILTRATION

A wide selection of porous media for filtration, diffusion, or aeration. Made of strong, chemically stable ALUNDUM* fused alumina, they also have high resistance to alkalies and acids. Provide uniform flow, with pores uniformly distributed in needed sizes and open-pore ratios. Tubes, plates, discs. Catalog No. 140 provides details.

FOR NUCLEAR WORK

Control and shield materials, including highly stable, lightweight NORBIDE* (B_4C). Metallurgical processing refractories. Ceramic fuel pellets. Source and intermediate materials.

FOR HIGH TEMPERATURE PROCESSING

Castables: Highly versatile, easy-to-handle ALUNDUM fused alumina materials for insulation. Provide protection up to 3300°F. Shipped dry in moisture-protective bags, they can be mixed in minutes. Small, lightweight bubbles or dense grains. Bulletin 1992 offers details.

Cements: Three different heat-resisting, chemically-inert materials carefully blended to assure proper grit-size distribution. ALUNDUM fused alumina, CRYSTOLON* silicon carbide, MAGNORITE* fused magnesia. For troweling, ramming, patching, pressing or brick-laying. Catalog 863 provides more information.

products

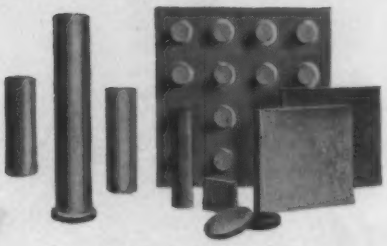
Ceramic Spray Coatings: Hard, crystalline materials which can be applied to a wide variety of base materials to provide thermal or electrical insulation, add mechanical strength, improve resistance to wear, corrosion, and chemical activity. ROKIDE* "A" aluminum oxide; ROKIDE "ZS" zirconium silicate; ROKIDE "Z" zirconium oxide. Bulletins available.

Fired Shapes: High-purity shapes of ALUNDUM fused alumina and fused stabilized zirconia offer excellent thermal insulation and chemical stability at high temperatures under both oxidizing and reducing atmospheres. CRYSTOLON silicon carbide products are available for processes involving heat transfer and abrasion resistance. Write for Catalog 862.

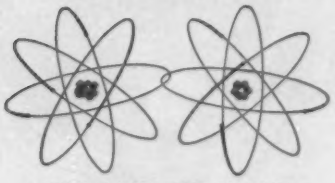
ALUNDUM ware has been used successfully for many years in laboratory development, experimental and analytical work involving filtering, extractions, melting, incineration, etc., because of its chemical resistance and stability in contact with reagents and solvents. Write for Catalog 793.

*Trade-Marks Reg. U.S. Pat. Off. and Foreign Countries

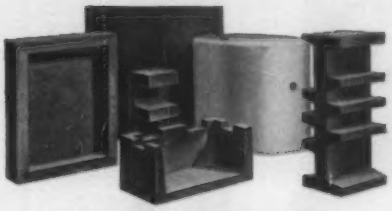
FOR CATALYSIS



FOR FILTRATION



FOR NUCLEAR WORK



FOR HIGH TEMPERATURE PROCESSING

FOR THE LABORATORY

NORTON

REFRACTORIES

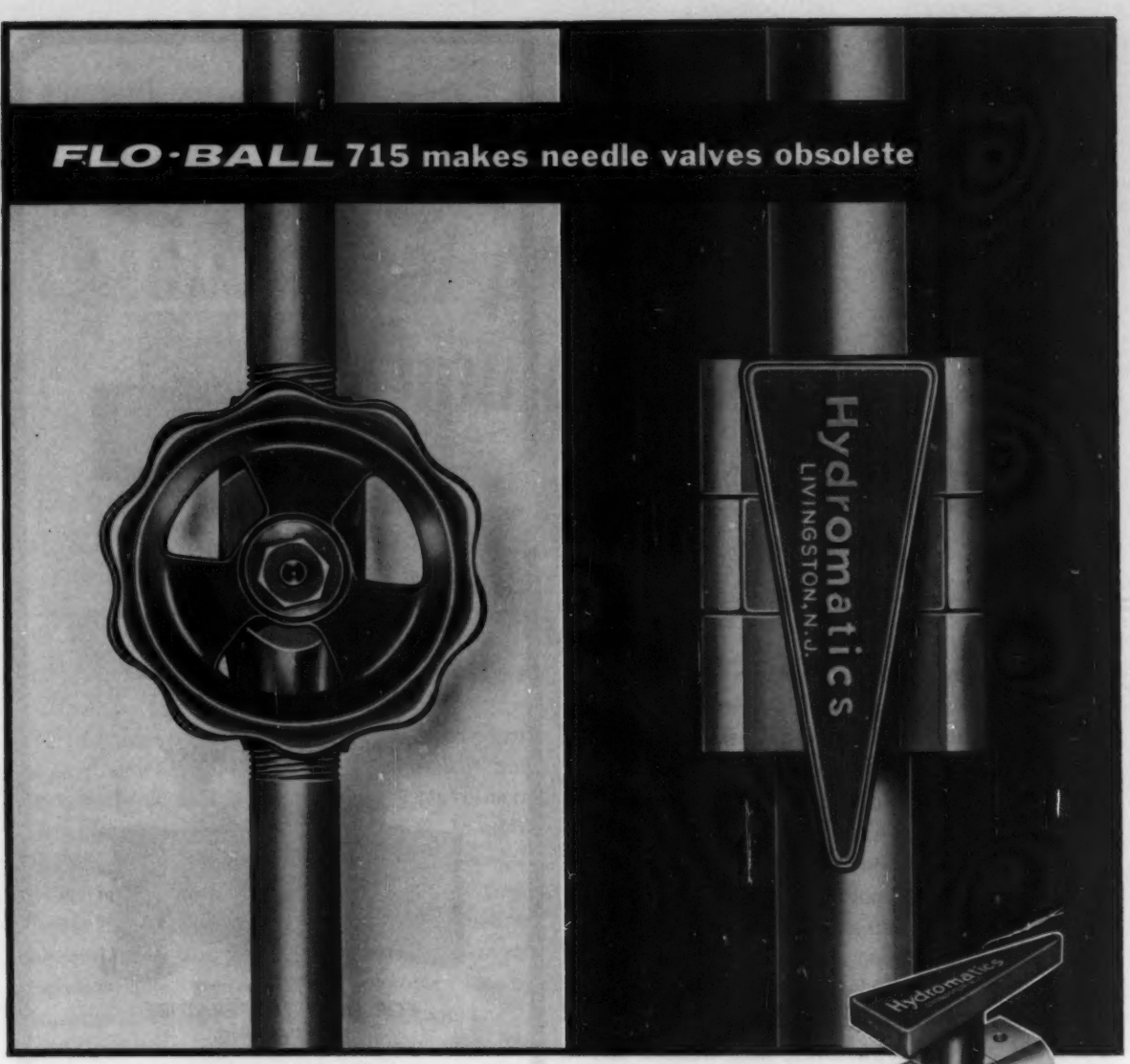
Engineered... Rx ...Prescribed

Making better products... to make your products better

NORTON PRODUCTS: Abrasives • Grinding Wheels • Grinding Machines • Refractories • Electro-Chemicals — BEAN-MANNING DIVISION: Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes

For more data on advertised products, use Readers' Service Cards, last page.

FLO-BALL 715 makes needle valves obsolete



WHICH VALVE IS OPEN?

They both are . . . but only the Hydromatics ***FLO•BALL 715,*** on the right, shows its position at a glance! A fast **quarter** turn moves it from open to closed position—instant action at flow pressures up to 3,000 psi with just 4 inch-pound torque. The ***FLO•BALL's*** exclusive straight-thru design has 100% flow efficiency—more than double the flow of needle valves!

Ideal for leakproof control of air, vacuum, steam, water, fuels, oils, kerosene, alcohol, etc., the ***FLO•BALL*** features zero leakage, universal mounting, removable flanges, and all stainless steel construction.

Write today for a complete catalog describing this valve and others for corrosive and cryogenic media. Also special designs for throttling flow control.

The *FLO•BALL* costs no more than old fashioned screw-type valves!

Hydromatics, Inc.

LIVINGSTON, N. J. • WYMAN 2-4900 • TWX = LIVINGSTON, N. J. 120

FLO-BALL

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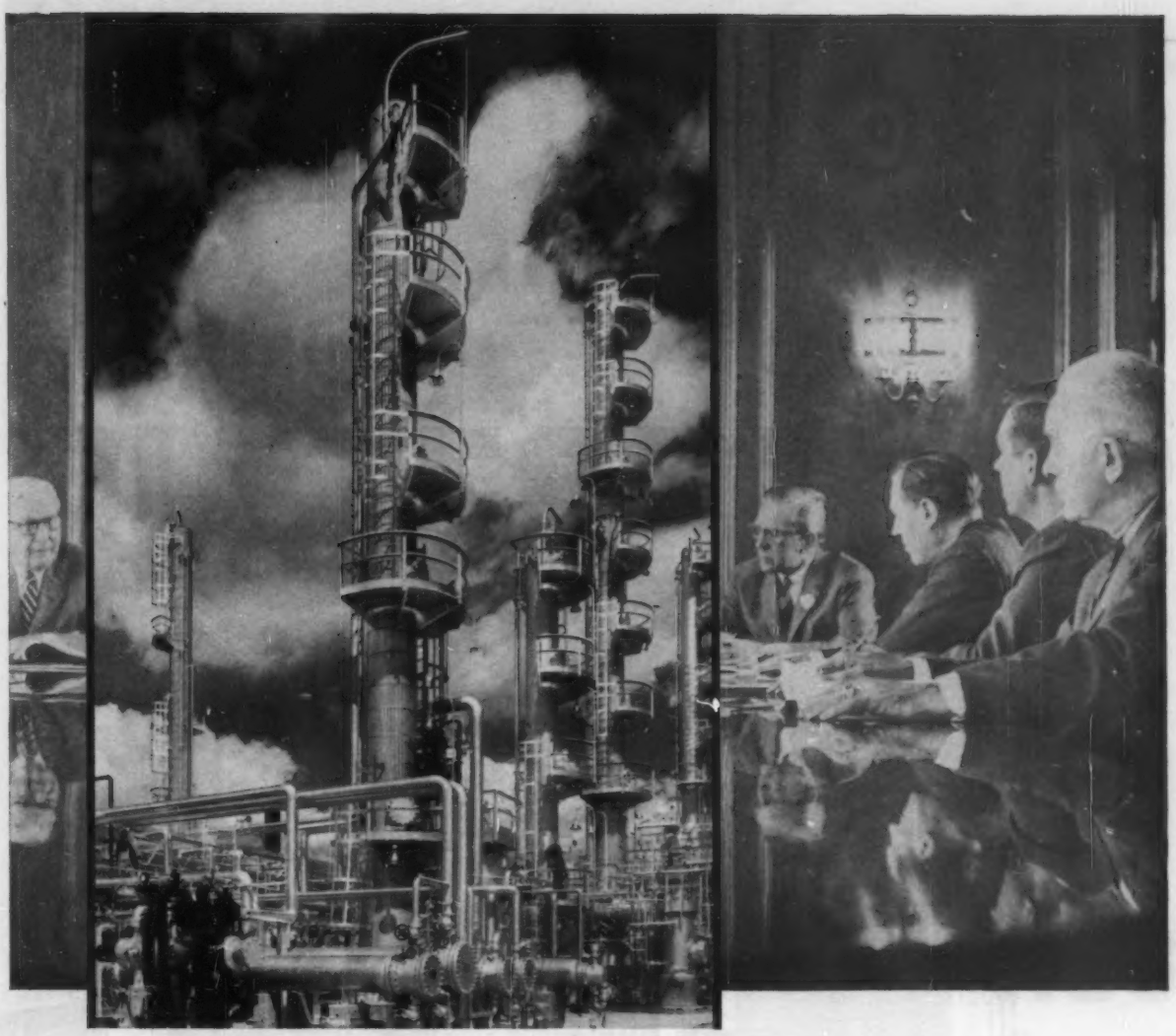
Exceptional engineering employment opportunities—write today!



Pritchard applies automatic data logging with, above all, GOOD FINANCIAL DESIGN

Socony's new 6000 bbl/day catalytic reforming unit at Casper, Wyoming might have been just another refinery addition–except for one vital difference. Along with the usual vessels and piping, J. F. Pritchard & Co., engineers and builders of the unit, provided a complete data logging and scanning system to monitor processes. This centralized automatic system supplements manual supervision and contributes to more efficient operation. The end result is lower operating costs and more profitable refinery operation.

The construction of this ultra-modern refining unit is an example of how Pritchard looks beyond the obvious to engineer and build plants with good financial design – the "extra" that gives Pritchard clients maximum return on capital.

Pritchard's experience in petroleum ranges from the design, engineering and construction of individual processing units to complete refineries. Pritchard also serves the oil field processing industry with facilities for operations such as sulphur removal and recovery, natural gas dehydration and pressure maintenance. If you are considering new construction in these fields, ask Pritchard to show you how good financial design can work for you.

PROVIDABLE FACILITIES THROUGH GOOD FINANCIAL DESIGN

J.F. Pritchard & Co.

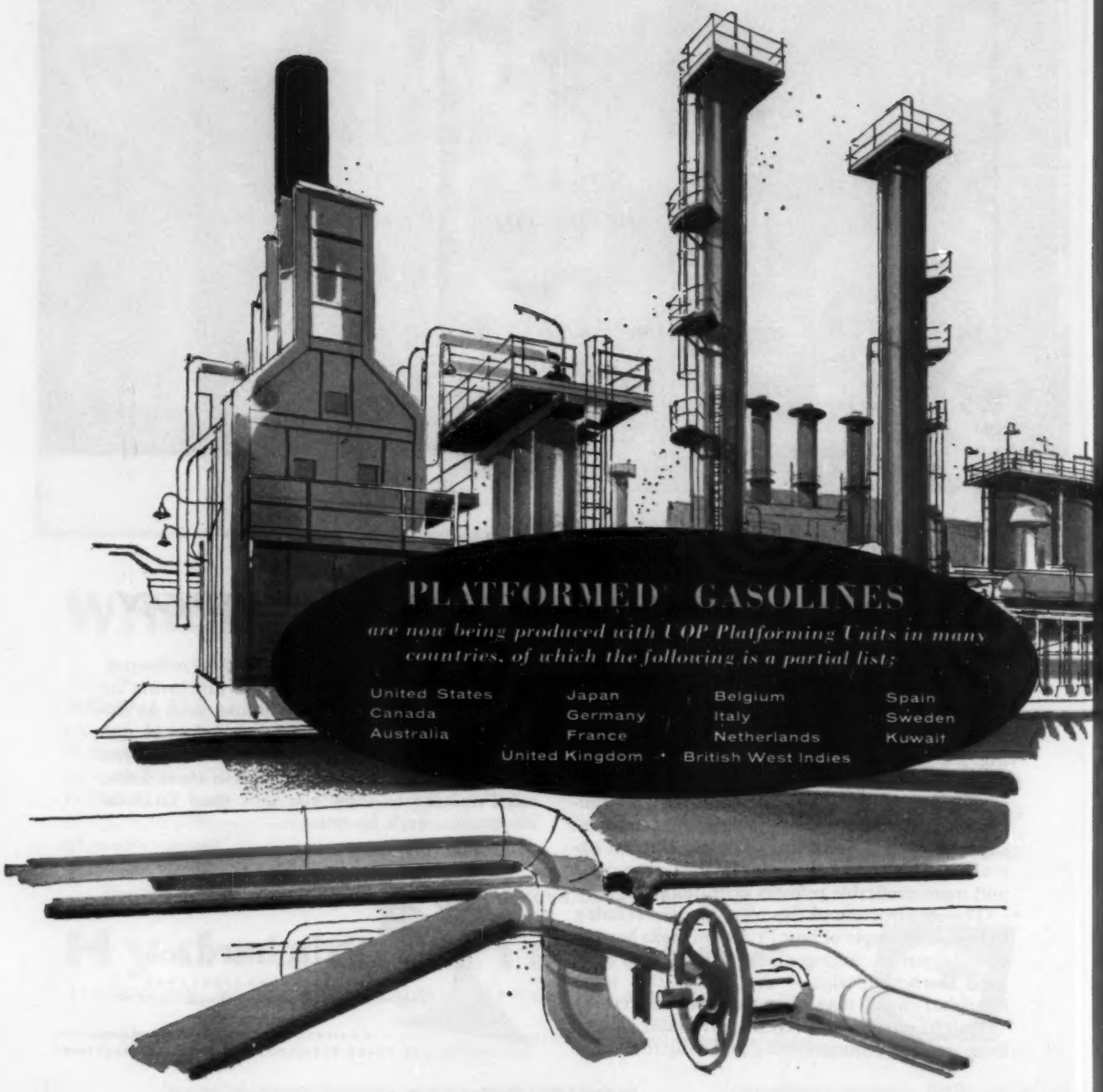
ENGINEERS • CONSTRUCTORS

Dept. 406, 4825 Roanoke Parkway, Kansas City 12, Mo.

OFFICES IN CHICAGO, HOUSTON, PITTSBURGH, NEW YORK

SERVING THE GAS, POWER, PETROLEUM AND CHEMICAL INDUSTRIES

1949 a decade



PLATFORMED GASOLINES

are now being produced with UOP Platforming Units in many countries, of which the following is a partial list:

United States	Japan	Belgium	Spain
Canada	Germany	Italy	Sweden
Australia	France	Netherlands	Kuwait

United Kingdom · British West Indies

1959 of better gasolines through PLATFORMING®

Petroleum refiners throughout the Free World have already supplied motorists with nearly 50,000,000,000 gallons of

Platformed® Gasolines

This year marks an important anniversary . . . the anniversary of an announcement that made significant history throughout the petroleum refining industry.

In March of 1949, Universal announced an important achievement in the field of catalytic reforming. In October of the same year, the first Platforming unit was placed in operation at a Muskegon, Michigan refinery. The new process, Platforming, literally revolutionized the entire concept of processing to improve motor fuels. It made previous methods of refining completely obsolete.

In addition to its value in producing superior Platformed gasolines, Platforming has also proved highly efficient in producing aromatic hydrocarbons, thereby providing the basis for the great petrochemical developments which have since taken place.

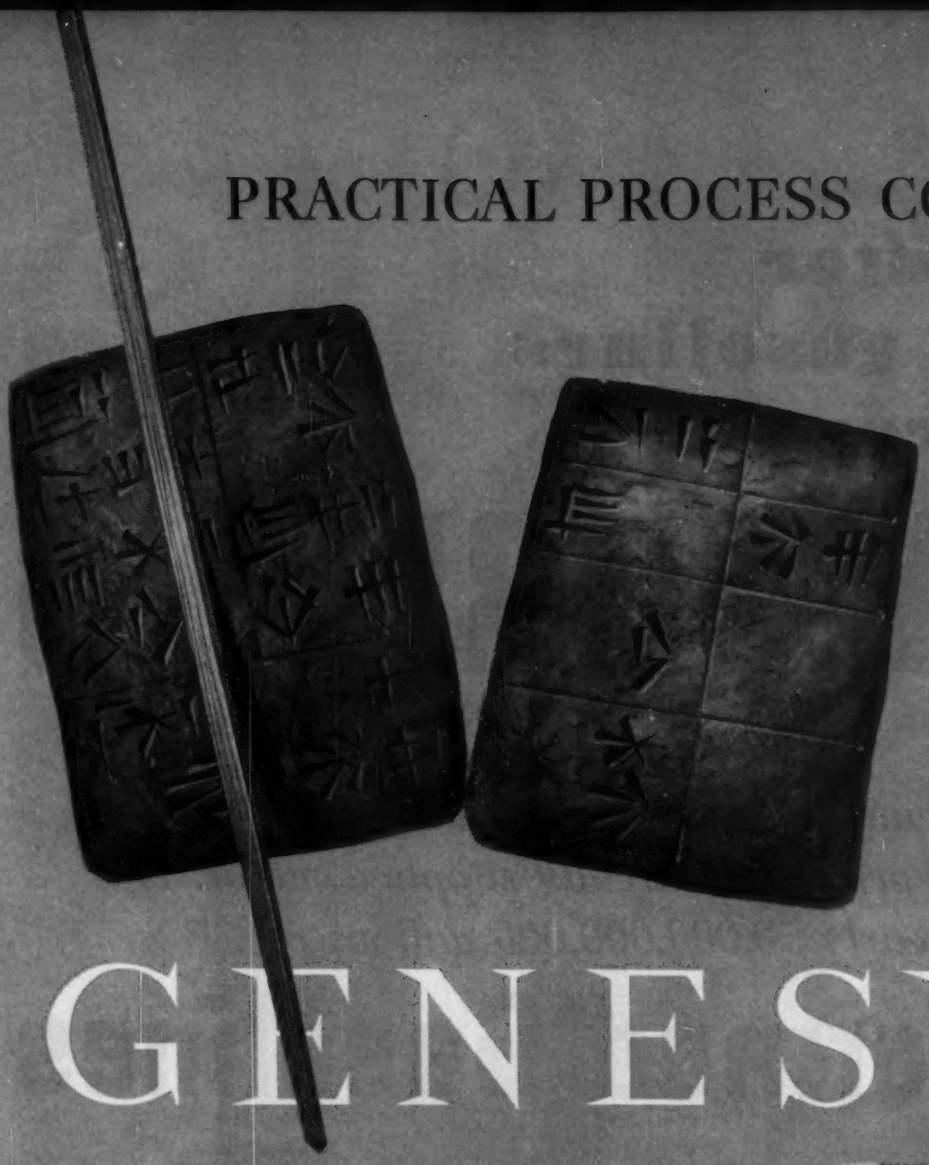
The rest of the story is a matter of history. Though many improvements and modifications have since been made, the same basic Platforming process has been applied by refiners throughout the Free World, and now accounts for a large proportion of all the reforming carried out today.

UOP®

UNIVERSAL OIL PRODUCTS COMPANY

30 Algonquin Road, Des Plaines, Illinois, U.S.A.

PRACTICAL PROCESS CONTROL



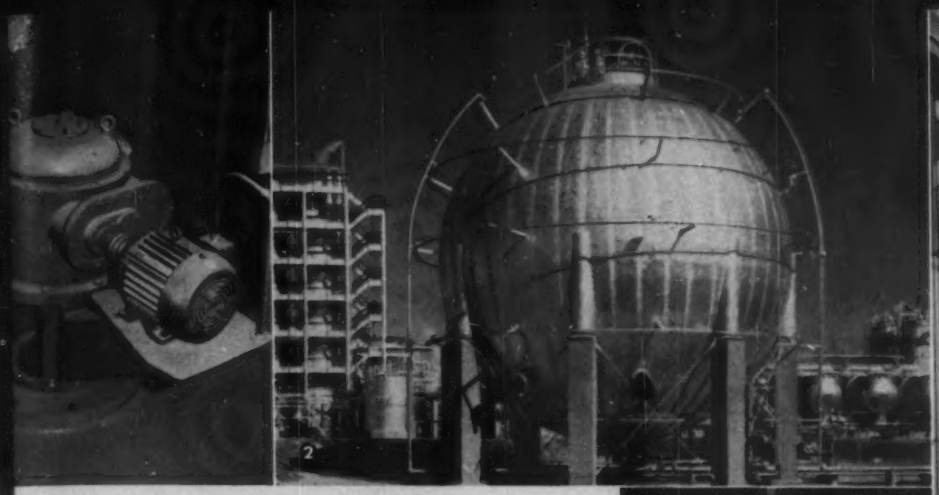
GENESYS

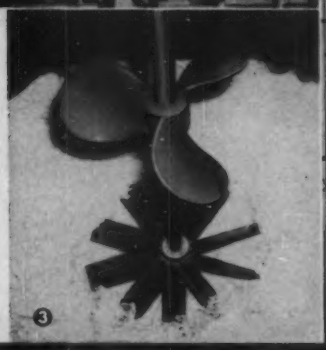
Designed from inception for process control, Genesys advanced digital control computer systems provide many exclusive advantages with unprecedented economy. Knowledge of precise process dynamics is not required. You can *optimize* process operations using your present instrumentation. You get unmatched reliability through practical design, practical computer speed matched to the problem -- thus fewer and only the most proven components. Genesys Systems deliver 4,000 hours of continuous, non-stop operation between scheduled maintenance periods . . . dependability with simplicity of operation at low cost . . . seven giant steps forward in process and pipeline automation. Write for "Evolution in Process Control."

Filling the void in practical digital control, this Unit Memory Processor (UMP) is the heart of a Genesys Process Control System, uses the best combination of general purpose and incremental computer techniques.

GENESYS CORPORATION G 10131 NATIONAL BLVD., LOS ANGELES 34, CALIFORNIA

A Subsidiary of CHANCE VOUGHT AIRCRAFT





Ore purification in pressure vessel with Nettco tank top turbine mixer.

Butadiene blending with Nettco side drive mixers having replaceable, mechanical seals.

Violent agitation as produced by Nettco's unique combination of turbine and propeller drives.

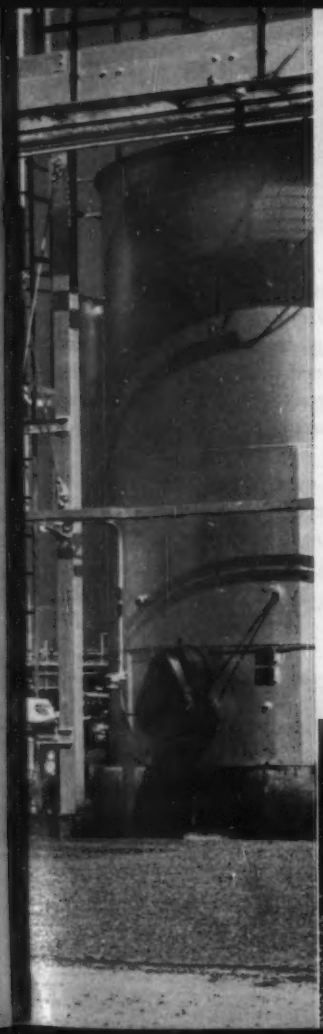
Maintaining product uniformity in Styrene storage tanks with Nettco side drive mixers.

Blending with Nettco side drive mixer in storage tank containing 20% caustic solution.

Small batch blending with versatile Nettco portable mixer.

Standardization of finished product with rugged Nettco vertical turbine mixers.

Improved Processing through Engineered Agitation



WHAT'S THE BEST MIXER FOR YOUR PARTICULAR JOB?

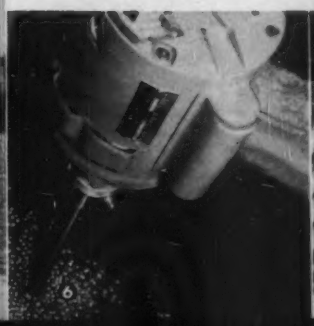
FLUID MIXING demands specialized, highly technical know-how. There is no single mixer which is "best" for every job. Only a mixing specialist can combine and coordinate agitation technology with mixer design and optimum horsepower to achieve an exacting result.

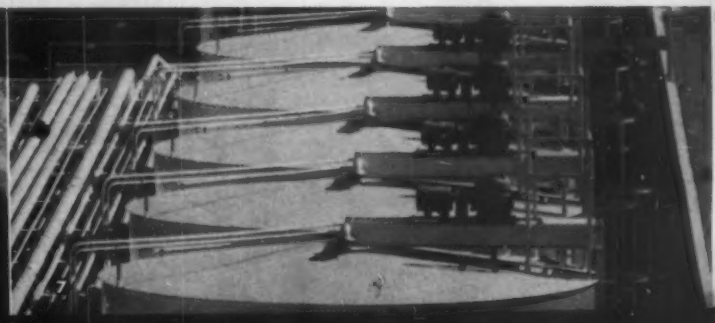
NETTCO ENGINEERED AGITATION provides a full evaluation of all application specifications, an analysis of performance data from pilot runs, and the careful selection of high quality, standard Nettco components to suit the specific job. *You* are assured of the result you want.

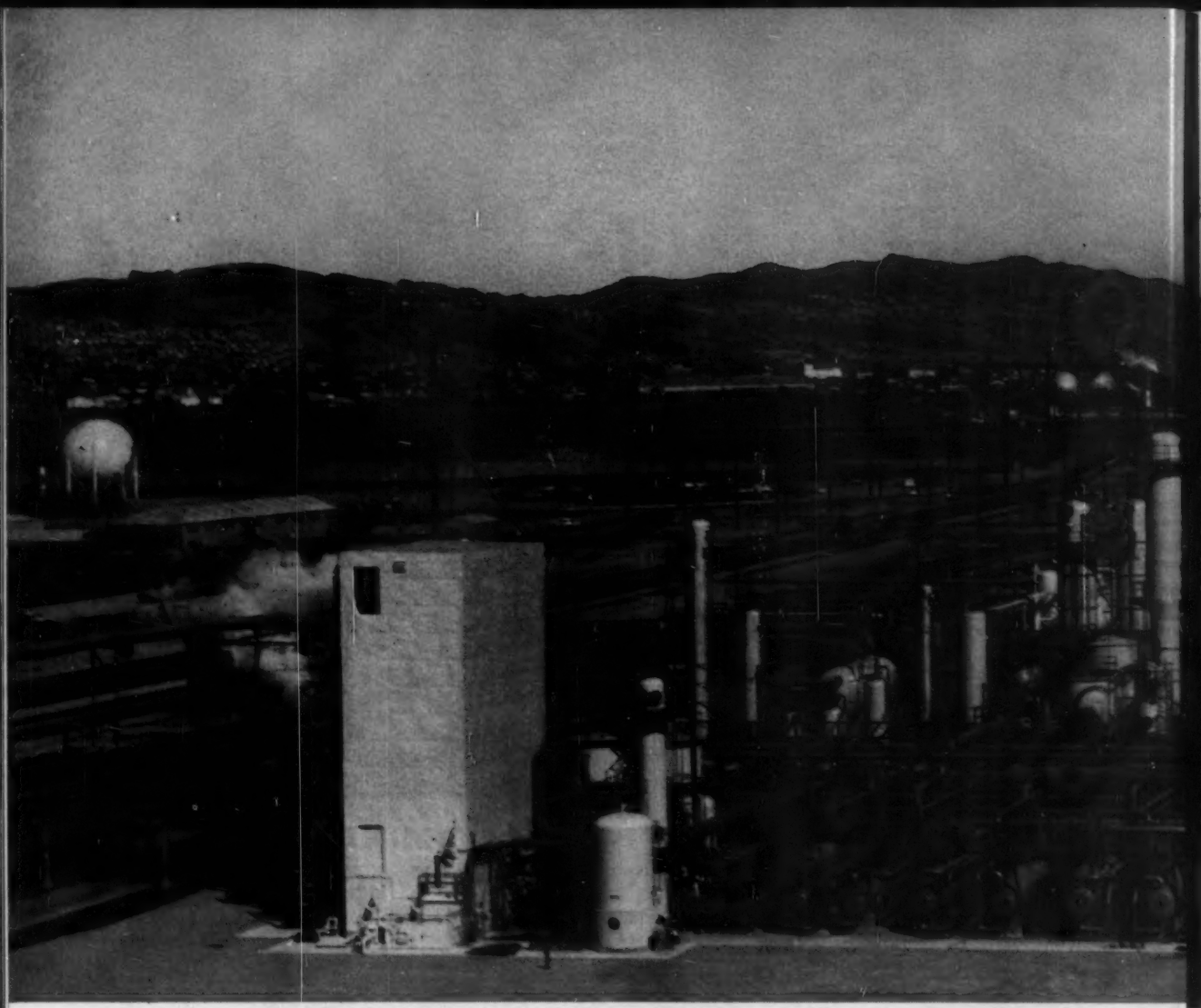
BACKED BY A FULL LINE . . . side drive, tank top, portable or tripod and continuous pipeline mixers . . . and thousands of performance-proven installations, like those illustrated, NETTCO can provide invaluable help in determining your fluid mixing needs. See *Chemical Engineering Catalog* or *Refinery Catalog* for our nearest representative, or write for Bulletin 581, NETTCO CORPORATION, 81 Tileston Street, Everett 49, Massachusetts.

NETTCO

ENGINEERED AGITATION SPECIALISTS



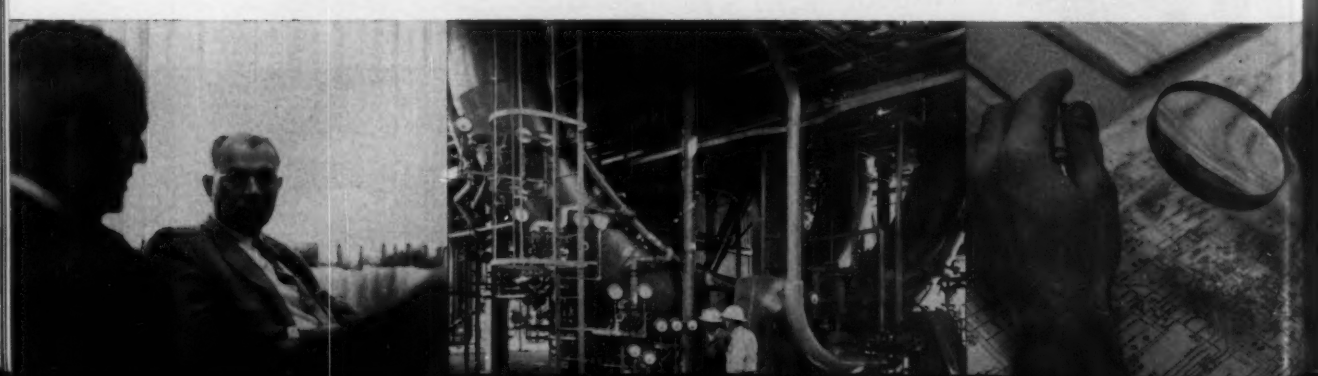


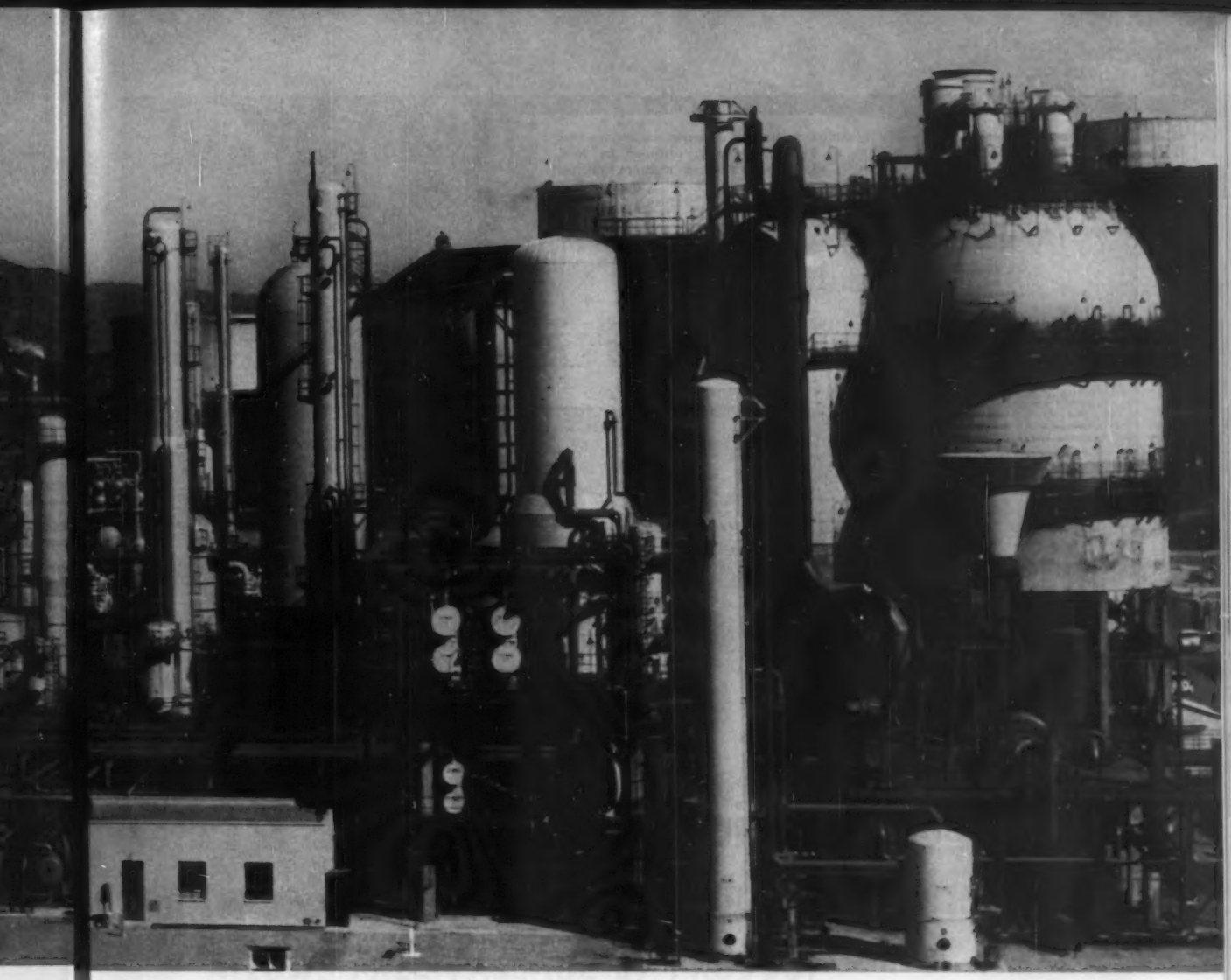


What's new in cat crackers?

The art of catalytic cracking has reached a highly advanced state. The improvements and refinements that now take place as new crackers are built seem minor indeed when one recalls the series of spectacular breakthroughs that followed one after another during cat-cracking's first eventful decade.

Yet there is drama even today. Sometimes it takes the form of a successful race against time. A record of sorts was set recently when the unit above was completed by Fluor for Standard Oil Company of California at its Richmond refinery on San Francisco Bay. It is an Esso Model IV





Fluid Catalytic Cracker with a capacity of 55,000 barrels per day, and it was delivered to the customer in time for the summer marketing season—two weeks less than one year after work began.

It is one of the two largest Model IV's in existence. The other, of the same capacity, was built by Fluor in 1954 for Standard at El Segundo. The Richmond and El Segundo units are almost identical except for auxiliaries (Richmond has a fired heater, a CO boiler and water-treating facilities). A few minor design and material changes, based on experience at El Segundo, were incorporated into the new unit.

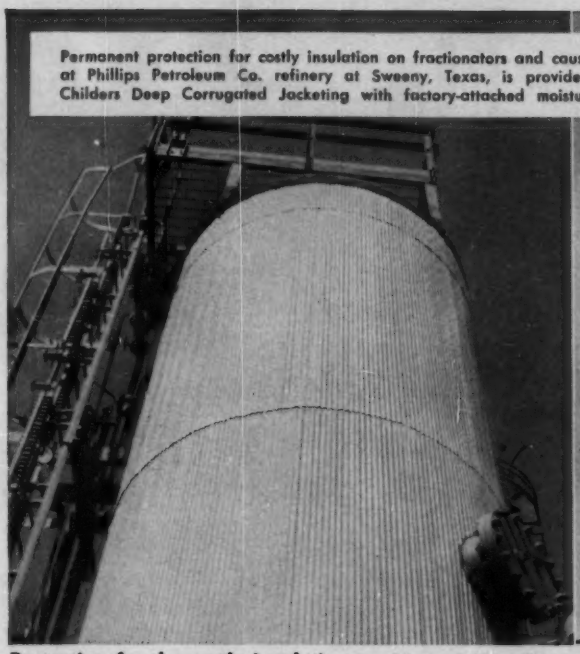
The job was begun on June 2, 1958, and completed May 15, 1959. Credit for the fast completion is due to many factors—organization, planning, fine co-operation from customer and suppliers, and good luck. But perhaps the most important element of all was Fluor's broad experience in the design, engineering and construction of cat crackers—nearly thirty of them since 1940.

A Fluor brochure, "FCC at Richmond," describes this interesting unit. Write to Dept. 54, The Fluor Corporation, Ltd., 2500 South Atlantic Boulevard, Los Angeles 22, California.

When you consider expansion...
the most important investment you can make
is in the creative ability of men

FLUOR
Engineers & Constructors

Permanent protection for costly insulation on fractionators and caustic washers at Phillips Petroleum Co. refinery at Sweeny, Texas, is provided by New Childers Deep Corrugated Jacketing with factory-attached moisture barrier.



Protection for the costly insulation on this caustic washer was applied in one easy operation because Childers Jacketing has factory-attached moisture barrier.

These gleaming aluminum-covered towers will always look new! No need to paint Childers Jacketing . . . a savings that alone may pay full cost of jacketing *plus* installation!

Why 724 plants specified this . . .

New Kind of Protection for Towers, Vessels & Tanks ...Childers Deep Corrugated Aluminum Jacketing:

Read why exclusive benefits of factory-attached moisture barrier are fast making Childers Jacketing the standard of the industry.

Only Childers gives you this special feature: Factory-Attached Moisture Barrier that (1) eliminates any danger of harm to the underneath side of the jacketing. And, (2) saves you time, labor and money because you apply jacketing with moisture barrier already attached . . . in one single operation.

You also get greater strength and greater protection at less cost with Childers Cross-Crimp®. Tests prove the rolled-in 3/16" cross corrugation increases the vertical strength and rigidity of .019" thick aluminum to that of plain .032" thick aluminum. Jacketing costs are consequently reduced as much as ⅓ when Childers Jacketing is used instead of ordinary sheet aluminum.

It's easy to install Childers Deep Corrugated Jacketing. Jacketing is applied with sheet metal screws used on both the vertical and circumferential lap. Screws may be omitted from circumferential lap when necessary to provide expansion joints.

Comes in two corrugations: 1¼" and 2½"; and four thicknesses: .016", .019", .020" and .024". The .019" and .024" thicknesses are made from roofing alloy for maximum life—recommended for normal jacketing of towers, vessels, and tanks. The .016" and .020" thicknesses are available in #3003-H-14 alloy.

For a free sample of Childers Deep Corrugated Aluminum Jacketing with factory-attached moisture barrier, plus engineering data on how to safeguard your insulation, write to Childers Manufacturing Company, Dept. PR-46, P.O. Box 7467, Houston 8, Texas.

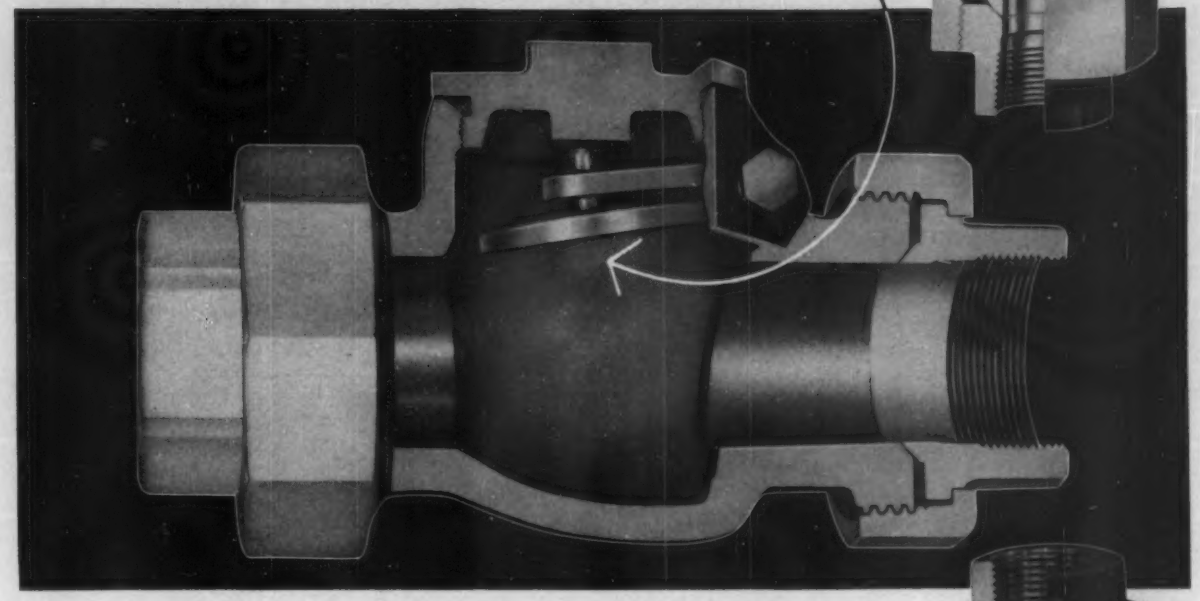
In Canada, write direct to Peerless Mfg. Co., Sub-Post Office 28, Calgary, Alberta.

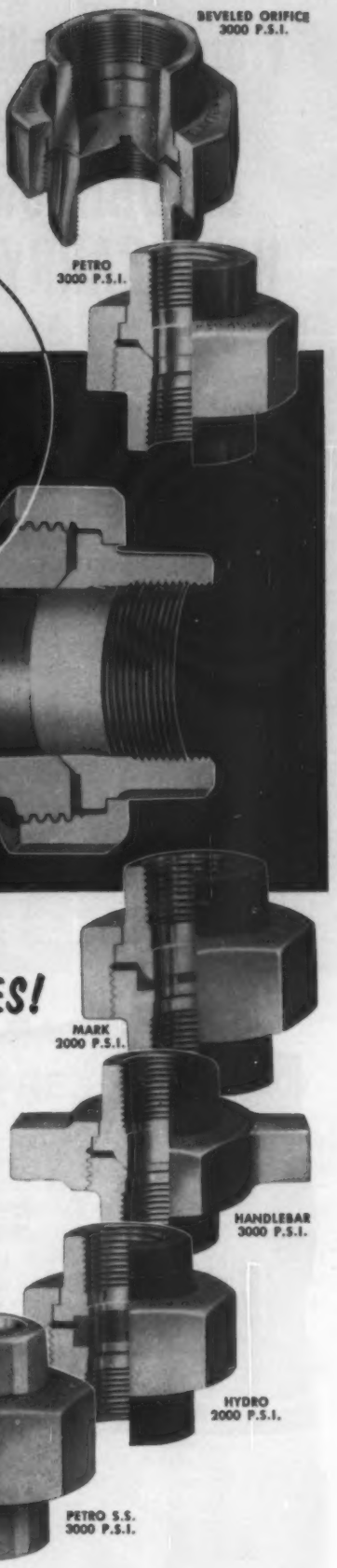
For insulated lines Childers Aluminum Weather-Proof Jacketing in rolls goes on about 30% faster than ordinary weatherproofing, fits perfectly, never needs painting. Used with Childers exclusive 90° and 45° Ell-Jacs, this modern aluminum protection gives your insulated lines that well-dressed look from end to end.

Only Childers makes available to you complete specifications and engineering data on aluminum jacketing in these catalogs: Refinery Catalog pp. 317-320; Sweet's Industrial Construction File pp. 10b/Ch; Chemical Engineering Catalog pp. 1011-1014.

Brand New!

CLAYTON MARK *full opening* UNION CHECK VALVE





ALLOWS FREE PASSAGE OF PRODUCT SEPARATING OR LINE CLEANING DEVICES!

- Full Opening Poppet
- Removable Stem
- Metal to Metal Seats
- Fits 2" Diameter Pipe
- Rated 500 P.S.I.—W.O.G.

New *full opening* Union Check Valve joins the family of Clayton Mark Unions . . . bringing to industry a top entry swing-check valve with superior features . . . offers many advantages especially for liquid processing. A pioneer in the manufacture of valves and steel unions, Clayton Mark has developed a complete line that serves as the industry's "yardstick" of quality and performance. When you want the best—specify C.M.!

Feature for feature CM Unions are superior!

CLAYTON MARK & COMPANY

1900 Dempster Street • Evanston, Illinois

For more data on advertised products, use Readers' Service Cards, last page.

From the wellhead through the refinery gate BRIDGEPORT TUBES HELP CARRY THE LOAD

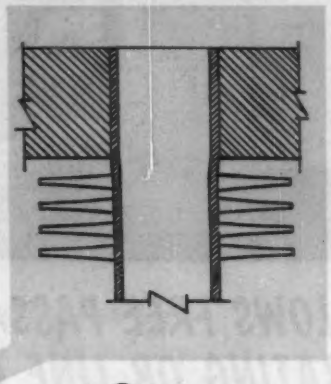
Right from the wellhead—Bridgeport is in the oil and gas production picture with aluminum, brass and copper base alloys in corrosion-resistant, single-wall and duplex tubes.

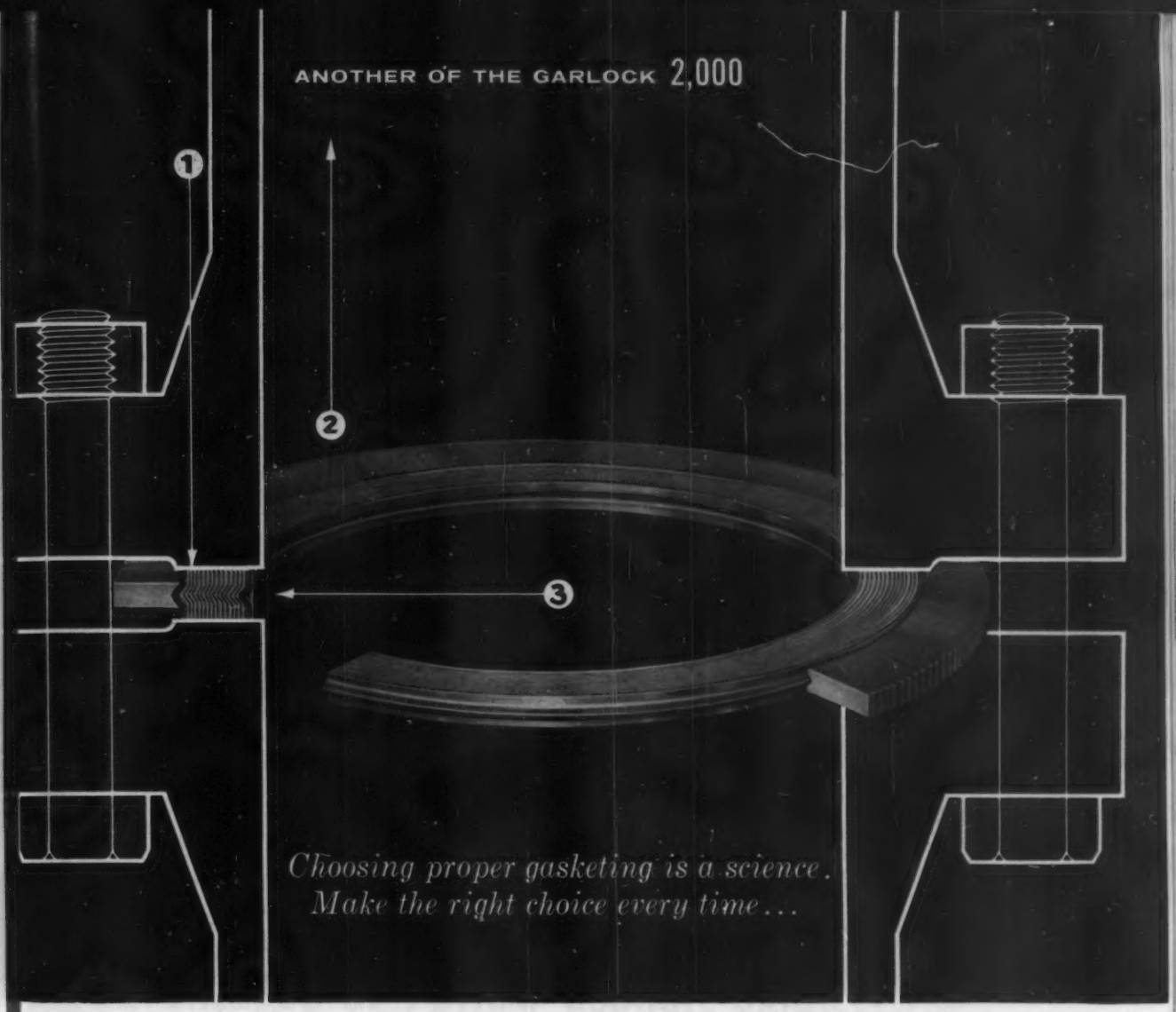
In natural gas production, for example, air-cooled heat exchangers at the wellhead do an around-the-clock job in both radiating the heat from the compressor engine and cooling the compressed gas before it is sent on its way to the gathering stations.

The air cooler illustrated here is manufactured by Air-X-Changers, Inc., Tulsa, Oklahoma. This model uses aluminum fins on Bridgeport Arsenical Admiralty condenser tubes. The tube bundles are mounted in a chamber, and fan-blown air across the finned surface cools either the compressor engine jacket water or the interstage and after-stage compressed gas. Bridgeport Inhibited Admiralty tubes are generally preferred for this type of service because of their corrosion resistance to both water and gas. And Bridgeport Aluminum Fin Stock is specially engineered for applications like this.

The range of Bridgeport condenser tube alloys—both single wall and duplex—is equaled by our vast experience in dealing with the special corrosive media encountered in the oil industry. This combination of quality products and technical engineering service pays you *all along the line.* Learn more about the benefits of Bridgeport Tubes and Technical Service for your applications. Write Dept. 5305.

Cross section of Air-X-Changer tube shows it expanded into tube sheet and individual aluminum fins positioned.





SELECT GARLOCK GUARDIAN* GASKETS FOR EXTREME TEMPERATURES, PRESSURES

Expertly-engineered GUARDIAN gaskets provide the necessary resilience and flow required by:

1. **BOLT LOAD** . . . seating force needed to make the gasket flow into the flange face imperfections to maintain tight seal against internal pressure
2. **HYDROSTATIC END FORCE** . . . pressure applied to a gasketed assembly by confined gases or liquids which tends to separate the flanges
3. **INTERNAL PRESSURE** . . . acts on the portion of a gasket exposed to the pressure side of a joint and tends to by-pass the gasket

Garlock GUARDIAN Gaskets are constructed of spiral-wound strips of V-shaped metal alternated with layers of asbestos paper or TEFLON†. By increasing or decreasing the number of layers the compressibility of GUARDIAN gaskets can be changed to meet different pressure and bolt loads—in no other type gasket can this be done!

Where operating conditions are unusually severe, apply TEFLON Garlock GUARDIAN gaskets to assure safe, positive sealing against practically all chemicals at temperatures from −300°F. to +450°F. For service against oils, steam, gases, liquids, at temperatures as high as 1050°F., pressures to 2500 psi, use asbestos-filled GUARDIAN Gaskets.

GUARDIAN gaskets are another of the Garlock 2,000 . . . two thousand different styles of packings, gaskets, and seals for every need. The only complete line. Ask your local Garlock representative for his unbiased recommendations. Or, write for Folder AD-104.

THE GARLOCK PACKING COMPANY, Palmyra, New York

For prompt service, contact one of our 26 sales offices and warehouses throughout the U. S. and Canada.

*Registered Trademark †DuPont Trademark for TFE Fluorocarbon Resin

Canadian Division: The Garlock Packing Company of Canada Limited
Plastics Division: United States Gasket Company

GARLOCK

Packings, Gaskets, Oil Seals, Mechanical Seals, Molded and Extruded Rubber, Plastic Products

Stainless Steel beats high temperature sulfide corrosion

AT GULF OIL'S
PORT ARTHUR, TEXAS, REFINERY

These atmospheric and vacuum distillation units, until just recently, processed about 32,000 barrels of West Texas sour crude per day. The atmospheric tower, barely visible in the right background, fractionates the crude to produce wet gas, straight run gasoline, light naphtha, light and heavy furnace oil, atmospheric gas oil and reduced crude. The vacuum tower in the center fractionates the reduced crude into light and heavy vacuum gas oil and bottoms.

Stainless Steel is the most practical material to withstand high temperature sulfide corrosion in the lining of these units. Operating temperature in the bottom shell of the atmospheric tower is 600° F. and in the vacuum tower it's 680° F. The 5/64" Type 405 Stainless Steel lining in the vacuum tower has been in service for ten years, and it hasn't shown one sign of failure! The atmospheric tower was not originally designed with Stainless and later was found to be corroding so badly that a Type 410 Stainless Steel lining was installed in the lower part of the tower.

It pays to design with the right material from the start. If you need corrosion resistance and strength at high temperatures, there is no material that can match the performance and economy of Stainless Steel. Order USS Stainless Steel through your U. S. Steel representative or your local Steel Service Center.

USS is a registered trademark

United States Steel Corporation—Pittsburgh
American Steel & Wire—Cleveland
National Tube—Pittsburgh
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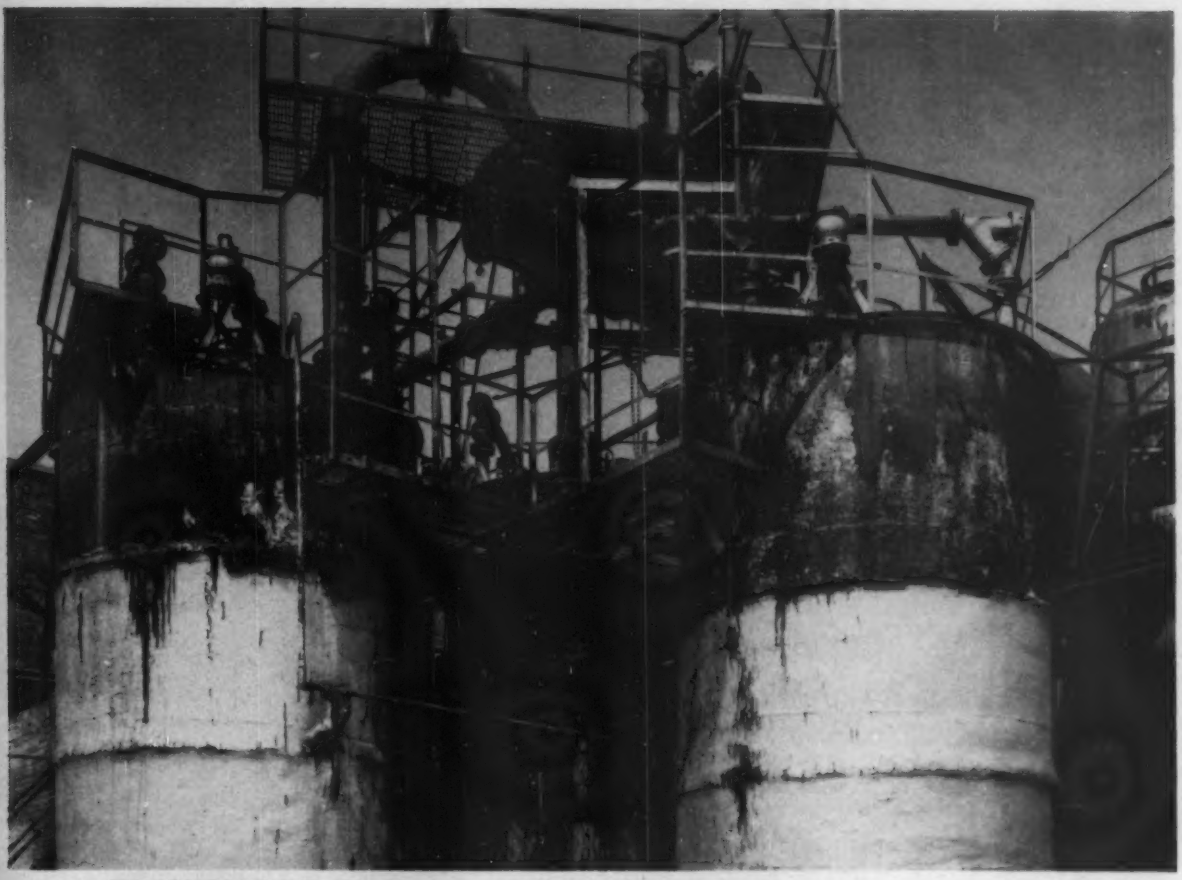
United States Steel Supply—Steel Service Centers
United States Steel Export Company

USS United States Steel



at FLINTKOTE'S Chicago Heights plant:

13 years continuous operation prove advantages of TURBO asphalt oxidizers

Thirteen years ago three General American TURBO asphalt oxidizers were installed at Flintkote Company's Chicago Heights plant. The units were piped to operate either individually as batch oxidizers for special products or in series for asphalt blowing. They require less than 15 hp each, and each is capable of handling up to 1000 cfm of air. They afford a rise in the melting point of asphalting material, varying from 12 to 20 degrees per hour, depending on the type of flux being produced.

For thirteen years the units have been in continuous operation, providing advantages of low power consumption, high air efficiency and accurate control of product specification.

The Flintkote installation is typical of TURBO asphalting equipment installed during a 25 year period to give higher production rates per still, lower power costs and less down time. TURBO units are safer to operate, need less top steam and less firing because of greater heat generation in the asphalt.

Ask for a TURBO engineer to discuss application of TURBO equipment to your needs.

FOR DETAILED INFORMATION AND USEFUL DESIGN DATA, SEND FOR THE FOLLOWING BULLETINS:

Please send me the following Turbo-Mixer Bulletin (s):

General Turbo-Mixer Bulletin_____

RDC Extraction Column Bulletin_____

Process Equipment Division

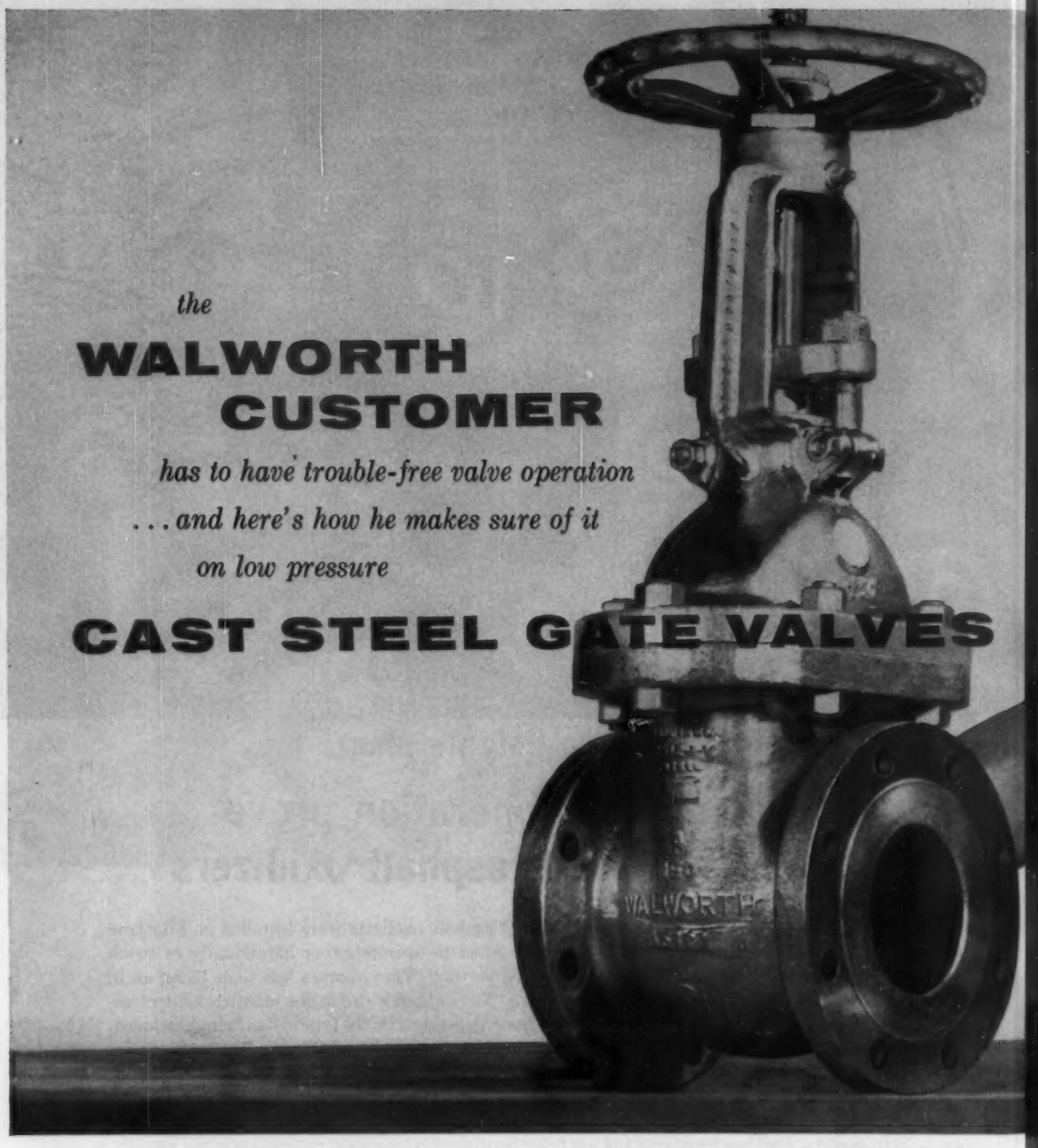
TURBO-MIXERS

GENERAL AMERICAN TRANSPORTATION CORPORATION

135 South LaSalle Street

Chicago 3, Illinois • Offices in principal cities

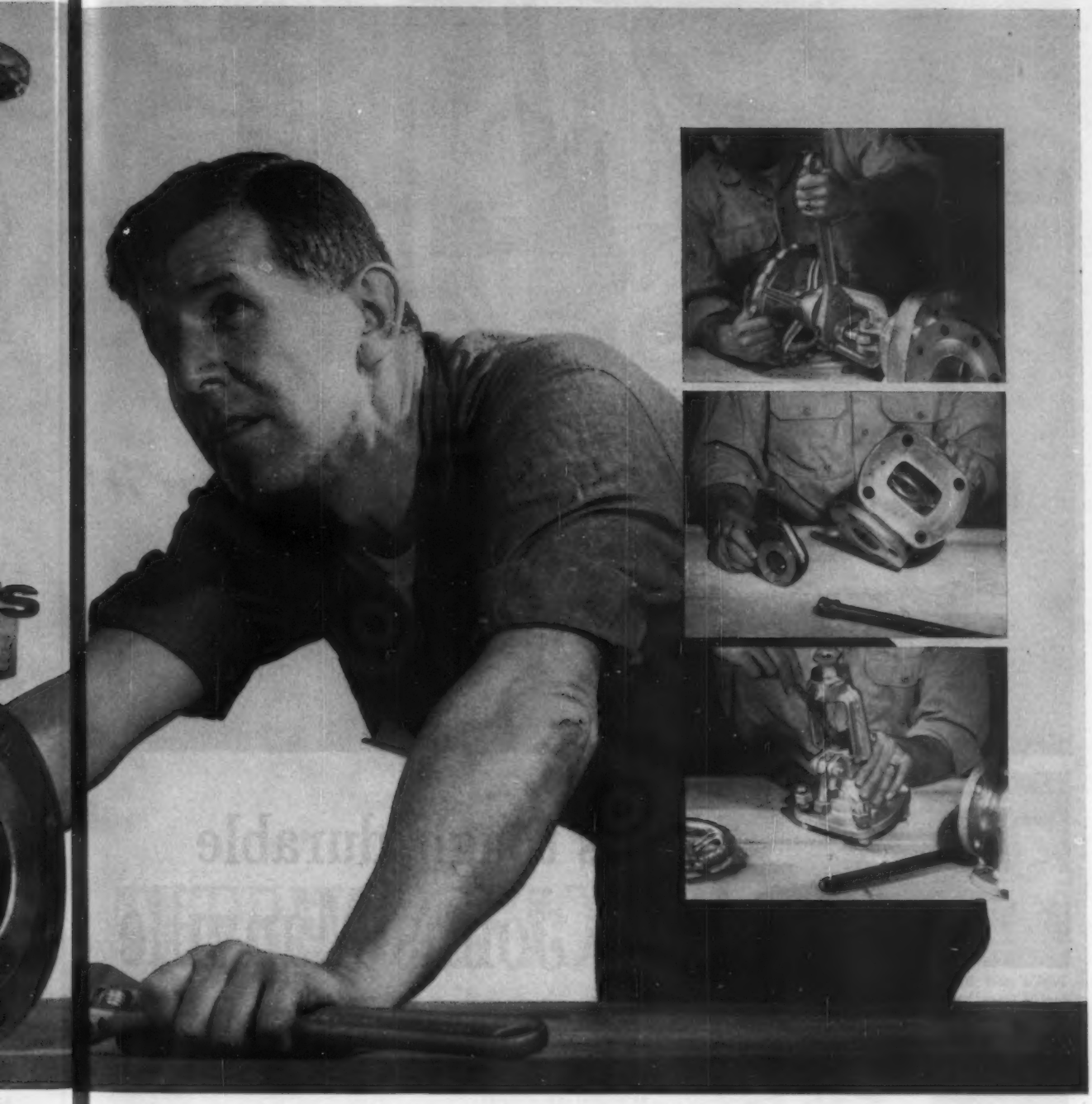
For more data on advertised products, use Readers' Service Cards, last page.



Before the Walworth Customer makes his decision on cast steel valves he gets persistently curious about things like these: What features reduce turbulence and pressure drop? Can body-to-bonnet joint be reassembled in the field without danger of misalignment? Is stuffing box deep enough to assure tightness and maximum life of packing?

In the Walworth Cast Steel Gate Valves he finds streamlined ports to fight turbulence and pressure drop. He finds flat gasket and male-and-female joint closures that assure correct realignment in field or shop reassemblies. He finds stuffing box depth adequate-plus for tightness and packing durability.

It's for customers like this man that

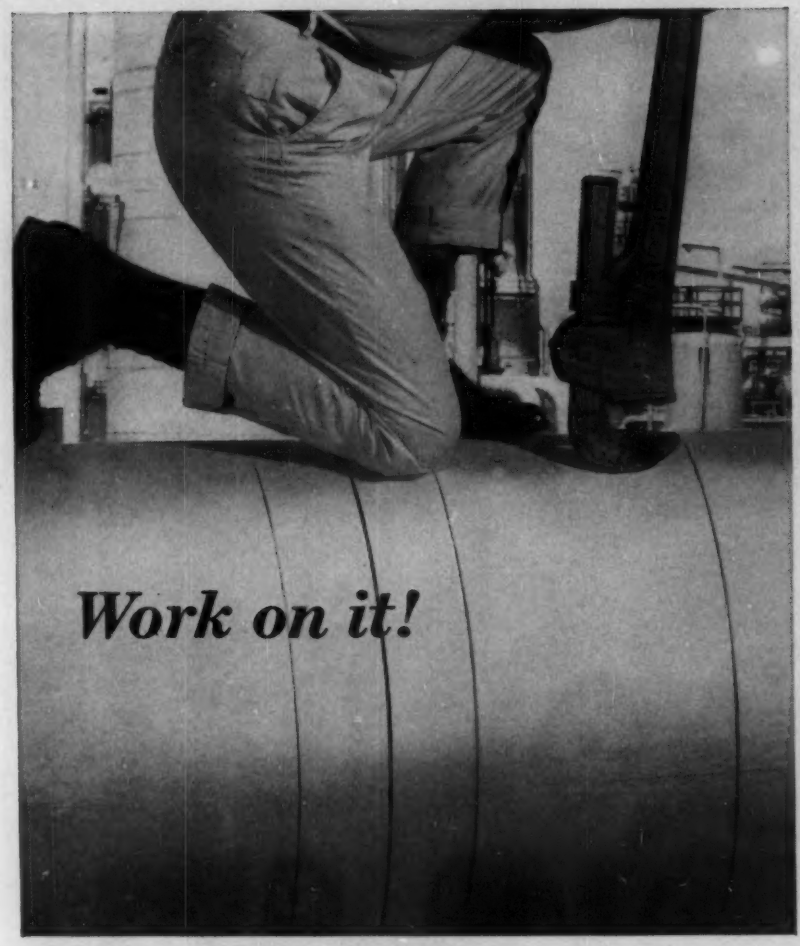


Walworth exists. We know he's hard to please, and we're proud to please him. If his exacting buying standards in valves are yours, too, we'd like you for a Walworth Customer. For details on all types and ratings of Walworth Cast Steel Gate Valves, or any of the complete line of Walworth Valves, contact your Walworth Distributor.

Or write **WALWORTH** *750 Third Avenue, New York 17, N. Y.*

DISTRIBUTORS IN PRINCIPAL CENTERS THROUGHOUT THE WORLD

WALWORTH SUBSIDIARIES: ALLOY STEEL PRODUCTS CO. • CONOFLOW CORPORATION • GROVE VALVE AND REGULATOR CO. M&H VALVE & FITTINGS CO. • SOUTHWEST FABRICATING & WELDING CO., INC. • WALWORTH COMPANY OF CANADA, LTD.



J-M's new Metal-On® insulation is Thermobestos prejacketed in aluminum. Snaps on pipe quickly . . . surely. Saves the time and cost of separate on-the-job metal application.

Seminars on best installation practices. For plant foremen who wish to keep up to date on new insulation methods and installation practices, J-M regional sales offices will gladly conduct insulation seminars. Contact nearest J-M office.

It's tough, durable Johns-Manville

Here's why Thermobestos is the preferred high-temperature calcium-silicate insulation . . . to 1200 F

You know the kind of treatment pipe insulation must take . . . day after day, year after year!

There's no better reason than this for the spiraling growth in Thermobestos® applications throughout the process and power generation industries —an insulation so strong and rigid, so resistant to crushing and compression it is almost structural.

THERMOBESTOS insulation!

Equally important is the ability of Thermobestos to keep fuel costs low. Its *k* factor is the lowest of all insulations generally accepted for process applications. Its moisture resistance, unsurpassed.

Furnished in large, lightweight sections—precision-molded to unusually close tolerances—Thermobestos is easy to handle and install . . . readily adaptable to shop fabrication of fittings and bonds. Large selection of sizes, thicknesses (and quads up to 33″ pipe size) permit calcium-silicate installations that are entirely Thermobestos insulation.

You'll want the new Thermobestos booklet for your technical file. It contains complete information on prefabricating and installation practices . . . specification data . . . heat transmission tables . . . and physical and thermal characteristics. Write for it today. Ask for booklet IN-169A. Address Johns-Manville, Box 14, New York 16, N.Y. In Canada, 565 Lakeshore Rd. East, Port Credit, Ontario.

JOHNS-MANVILLE PRODUCTS

JOHNS-MANVILLE

Which valve alloy for your next job?

When you next have a requirement for high alloy valves, especially for corrosion service, why not come to the company with the most experience in this field.

Aloyco has specialized in the manufacture of stainless steel valves, exclusively, for over 30 years.

We have accumulated a wealth of know-how, not only on how to engineer valves for hard-to-handle corrosives, but also on what alloys are the most efficient and will give the longest life.

Aloyco's field consulting service is yours for the asking. Why not write or call our nearest sales office for help on your next alloy valve job. Alloy Steel Products Company, 1303 West Elizabeth Avenue, Linden, New Jersey. 9.10

Offices in: Boston • New York • Wilmington Atlanta • Buffalo • Pittsburgh • Chicago St. Louis • San Francisco • Los Angeles

***These seven corrosion test specimens** are just a few from hundreds of tests conducted by Aloyco to insure our valve customers of the right alloy for their particular job. Aloyco valves are supplied in such metals as 304 and 316 stainless steel, Aloyco 20, Nickel, Monel and Hastelloy B, C and D.*

ALLOY STEEL PRODUCTS COMPANY
LINDEN, N. J.

This is THERMAL FATIGUE

This photograph shows a heat-resistant alloy casting after thermal-fatigue failure.

Thermal fatigue begins with cyclical heating and cooling which produces alternate expansion and contraction. The shape of the casting hinders this expansion and contraction. As a result, hindered expansion and contraction stresses develop and increase until plastic flow occurs. This plastic flow produces a network of thermal-fatigue cracks and this cracking leads to failure.

Thermal fatigue is an inherent problem in heat-resistant castings. As such, it occupies an important place in Electro-Alloys research efforts to lengthen life of components working under high temperatures and severe cyclical conditions.

We have created apparatus that assesses and analyzes the variables of thermal fatigue. Check with your Electro-Alloys representative for the meaning of our thermal fatigue data as it pertains to the material, design and service conditions of your heat-resistant castings.

View and discuss Thermal Fatigue at the Electro-Alloys Booth, 727, National Metals Exposition, International Amphitheatre, Chicago, November 2-6.

Send for free technical booklet on Thermal Fatigue

Please send me free copy of "The Mechanism of Thermal Fatigue," by Howard S. Avery—comprehensive report based on extensive lab studies:

Name_____

Title_____

Company_____

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Electro-Alloys, 1039 Taylor St., Elyria, Ohio

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION • Elyria, Ohio

HUDSON Combin-aire

LOW TEMPERATURE COOLING USING COMBINATION OF MINIMUM WATER AND MAXIMUM AIR

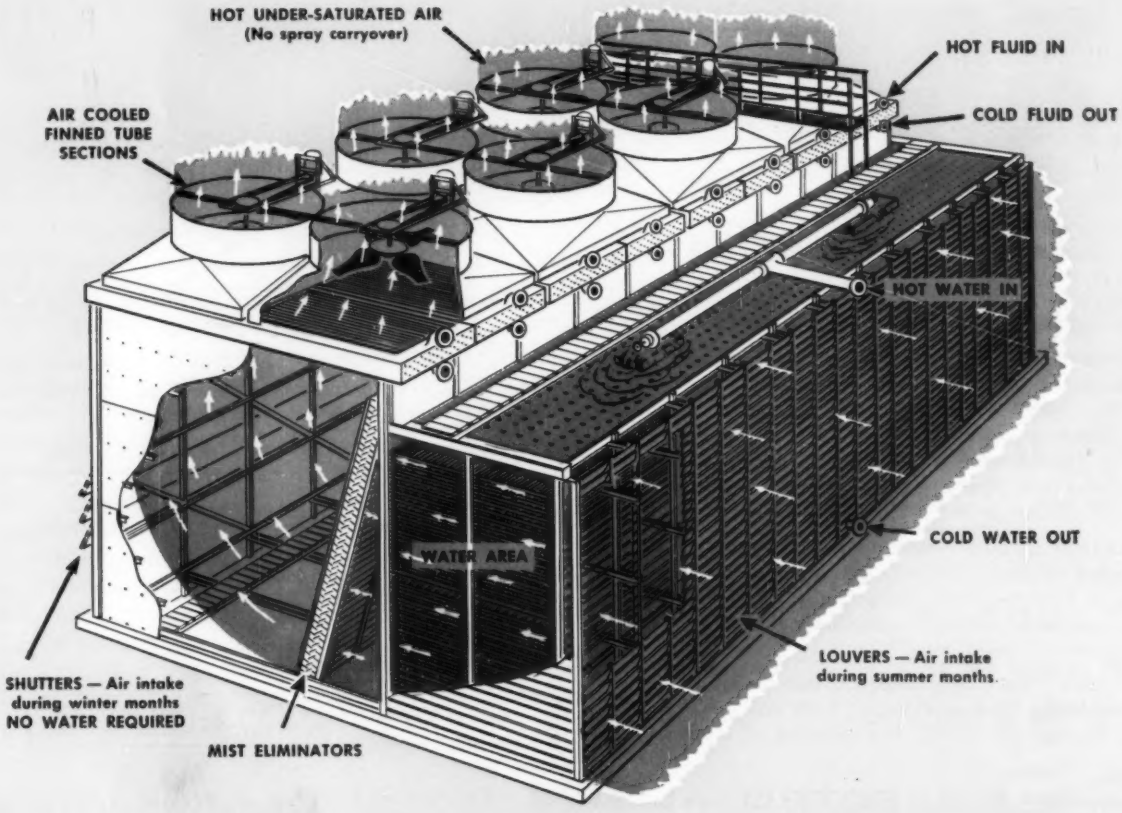
In recent years Hudson Solo-aire cooling in which only air is used as a cooling medium has been installed by the world's largest refineries. In recent cases of three separate 40,000 barrel complete refineries in locations where unlimited water is accessible Hudson Solo-aires are used for *all* process cooling.

So that air could be used for cooling those process streams requiring lower terminal temperatures than obtainable with ambient summer air temperatures, Hudson developed and in 1949 installed the first Combin-aire cooling unit. Since that time Combin-aires have proven their worth in installations for over 80 services in major refineries, chemical plants and gas processing plants in the United States, the Middle East, Europe, Mexico and South America.

In Combin-aire cooling, high temperature ambient air is first pre-cooled by direct contact with water, the cooled air then becoming the low temperature cooling medium for fin-tube elements. Cooling of air, and subsequent use of the cooled air for fin-tube cooling of process streams, are effected in one integrated structure — the Combin-aire.

Cooling with Combin-aire to overcome the occasional limitation of high ambient temperatures has the following advantages:

- **Absolute minimum water consumption consistent with attainment of low terminal process stream temperatures.**
- **Water circulation may be made automatically responsive to air temperatures with no water circulated except at high ambient temperature.**
- **No water treatment necessary. Salt water or brackish water may be used.**
- **No spray carryover or condensation. After passing across the fin-tube elements the heated air leaving the Combin-aire at elevated temperature is undersaturated with water vapor and cannot precipitate condensate or carry water spray.**
- **Minimum piping. Combin-aire may be installed immediately adjacent to other process equipment.**
- **Clean air to fin-tube units. During the hot season air is washed, removing dust, sand and insects.**



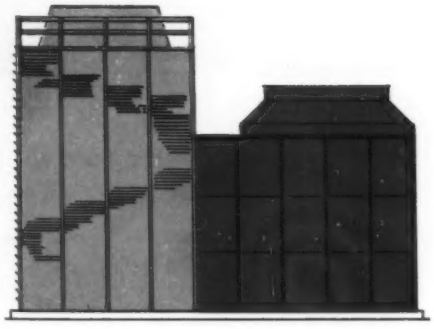
When Combin-aires are installed as adjuncts to cooling systems using existing shell and tube or other water cooled equipment the cooled water from the bottom of the Combin-aire may be used in such equipment. The Combin-aire then takes on the additional function of a water cooling tower with, however, the advantages over conventional cooling towers of dual use of both air and water and elimination of water spray carryover and condensate precipitation.

In over 80 services and under a wide range of atmospheric operating conditions Combin-aire units have amply fulfilled performance and mechanical specifications. Before proceeding with a new process unit or revamping or adding to present cooling systems let Hudson give objective assistance in determining the most economic balance in the use of air cooling, Combin-aire cooling and water cooling.

CONVERTING COOLING TOWERS INTO COMBIN-AIRE UNITS

Presently installed cooling towers may be used as the basis for Combin-aire cooling by installing structure with fin-tube elements and fans immediately adjacent to the cooling tower with air for the fin-tube elements being drawn across the water near the bottom of the cooling tower, thus increasing the capacity of the cooling tower, and cooling the air for use in the fin-tube elements.

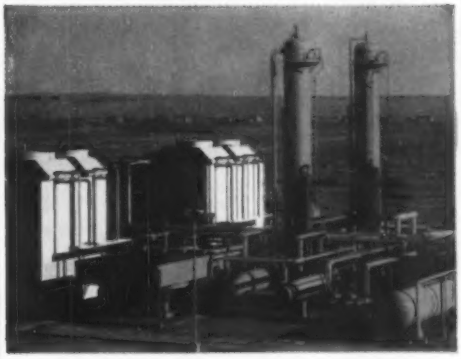
EXISTING COOLING TOWER **COMBIN-AIRE ADDITION**



Combin-aire is protected by U. S. Patents, Patents pending and copyrights.

TEXAS —
COSDEN PETROLEUM CORPORATION
Big Spring, Texas

MEXICO —
PETROLEOS MEXICANOS
Reynosa, Tamaulipas, Mexico

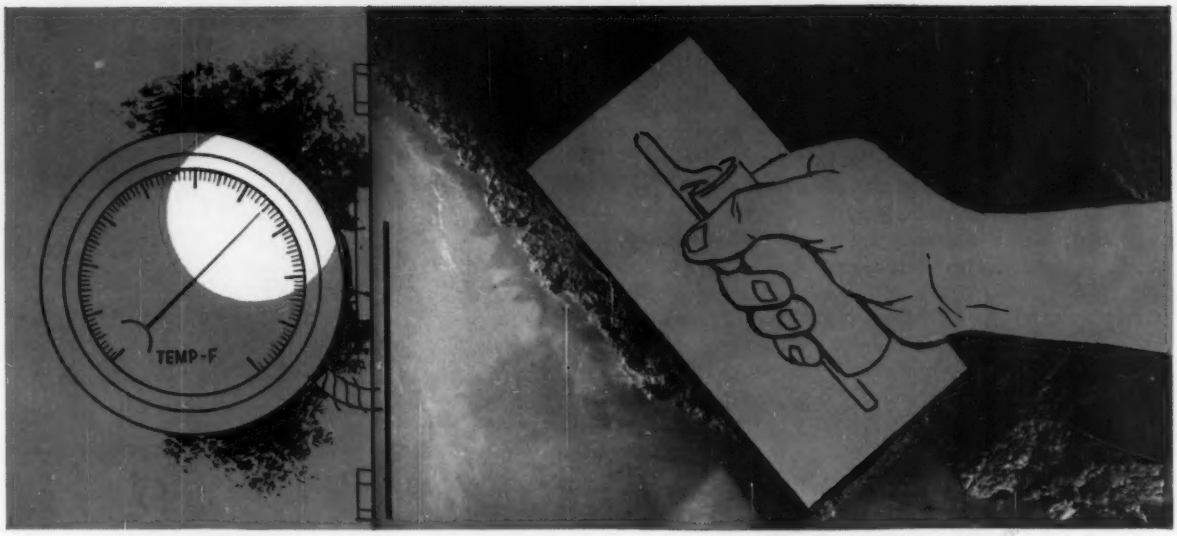


PAKISTAN —
PAKISTAN PETROLEUM, LTD.
Sui gas field, West Pakistan

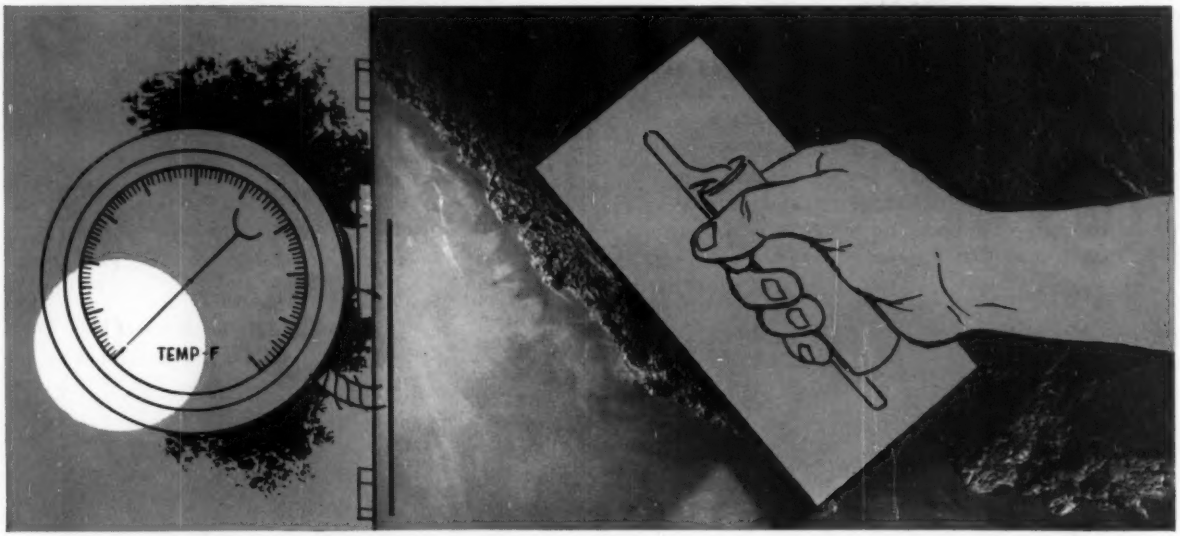
HUDSON
ENGINEERING CORPORATION
FAIRVIEW STATION • HOUSTON, TEXAS

SALES OFFICES:
9935 Santa Monica Blvd. Beverly Hills, California • 122 East 42nd St. New York, 17, N. Y. • 199 Bay Street Toronto, Ontario, Canada
17 Stratton St., Picadilly London W. 1, England • Corrientes 1115 Buenos Aires, Argen. • Rua Mexico 45 Rio de Janeiro, Brazil

HUDSON COOLING EQUIPMENT MANUFACTURED UNDER LICENSE BY:
A. F. Craig & Co., Ltd. Paisley, Scotland • Batignolles-Chatillon 5 Rue de Monttessuy Paris, France



IT STICKS TO HOT OR COLD SURFACES!



EAGLE-PICHER
SUPER "66"
INSULATING CEMENT

Eagle-Picher produces a complete line of industrial insulations for all temperatures from below Zero to over 2000 F.

EAGLE EP PICHER

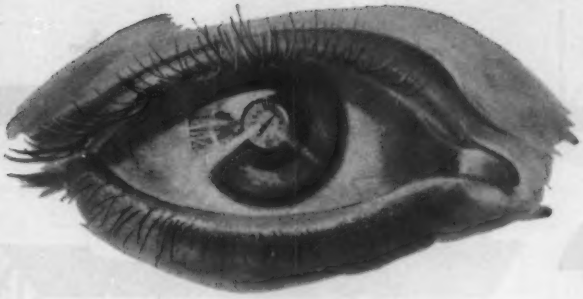
Since 1843

The Eagle-Picher Company
Dept. PR 9
General Offices: Cincinnati 1, Ohio

Here's why you save money when you use Eagle-Picher Super "66" Insulating Cement

- Because it sticks, Super "66" saves time — applies quickly to any equipment, cold or hot. Effective up to 1800°F. . . . and it contains a special rust inhibitive which actually prevents corrosion !
- Because it sticks, Super "66" saves money— provides far greater coverage and more efficient insulation.
- Because it sticks, Super "66" makes difficult jobs easy—can be used on irregular shapes where application of other insulations is often impossible. Usually requires no reinforcing on applications up to 1½ inches thick.

For more data on advertised products, use Readers' Service Cards, last page.



What you read is right

The new, patented Maxivision dial on American Bi-Metal Thermometers eliminates the perspective effect of usual pointer-above-dial construction. No parallax! Readings are sure, sharp and accurate – exact working temperatures are always right before your eyes. It is a two-level dial. A raised outer ring, set close to the cover glass, carries the graduations. The index type pointer is on the same plane as the outer ring, with the numerals on a lower level.

What you read is right when American Bi-Metal Thermometers with anti-parallax Maxivision dial are installed at important check points on your processing facilities. Mounting styles, dial sizes, temperature ranges and stem lengths are available to meet the most exacting requirements. Let your nearby industrial distributor help you select the best combination for each location.

American Bi-Metal Thermometer with Maxivision Dial. Suitable for indoor or outdoor service.

MANNING MAXWELL & MOORE INC. M&M TRADE MARK

AMERICAN INDUSTRIAL THERMOMETERS

A product of

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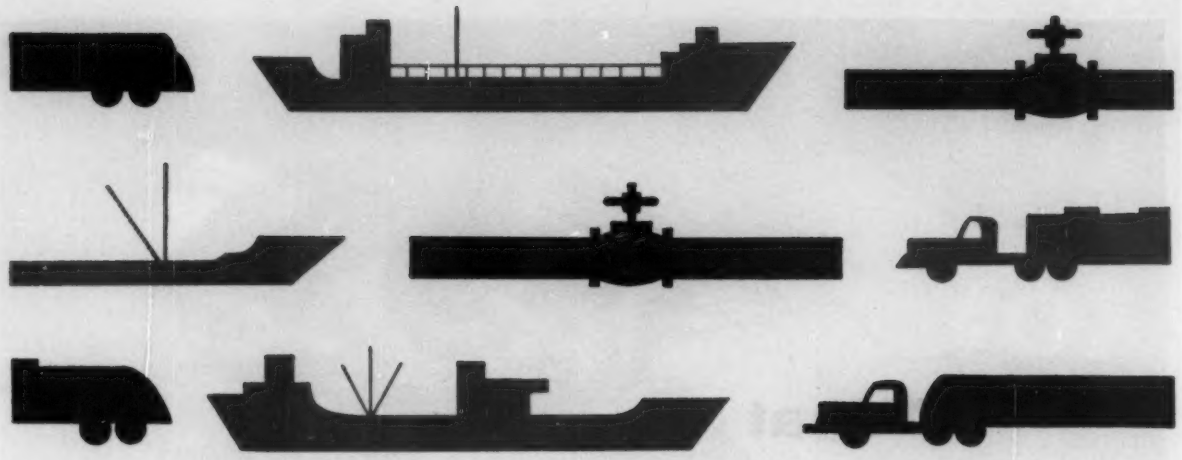
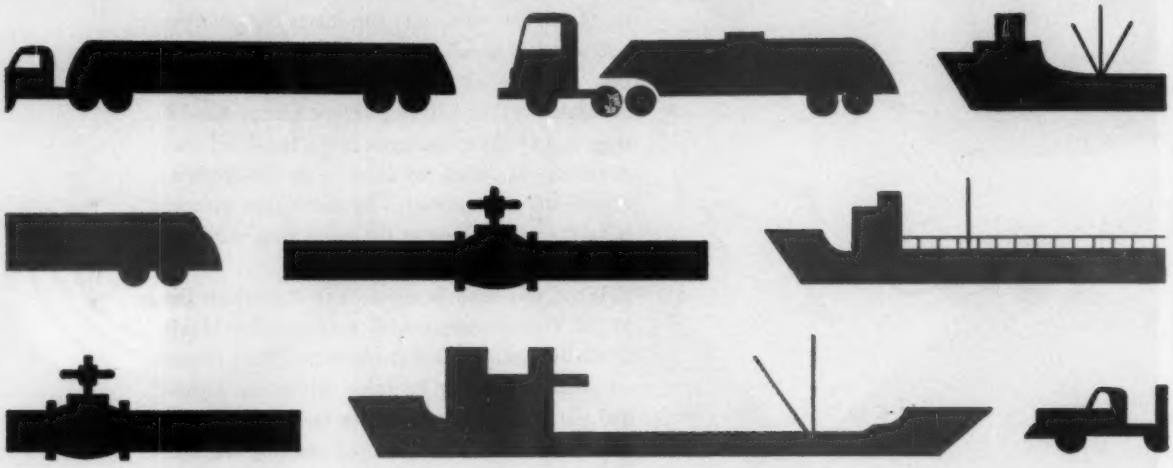
In Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario

For more data on advertised products, use Readers' Service Cards, last page.



FOR SAFE TRANSPORT-LAND AND SEA
SHAND AND JURS TANK FITTINGS



For over 35 years, Shand and Jurs has pioneered in the design and manufacture of mechanical tank fittings for truck tanks, marine tankers and pipeline installations. S&J offers petroleum transporters the world's most complete line of valves, gages, fittings and controls for maximum safety and economy in the movement of petroleum products. Convenient Shand and Jurs branch offices and sales representatives are ready now to help you with your tank fitting problems. Call them today.

SHAND AND JURS

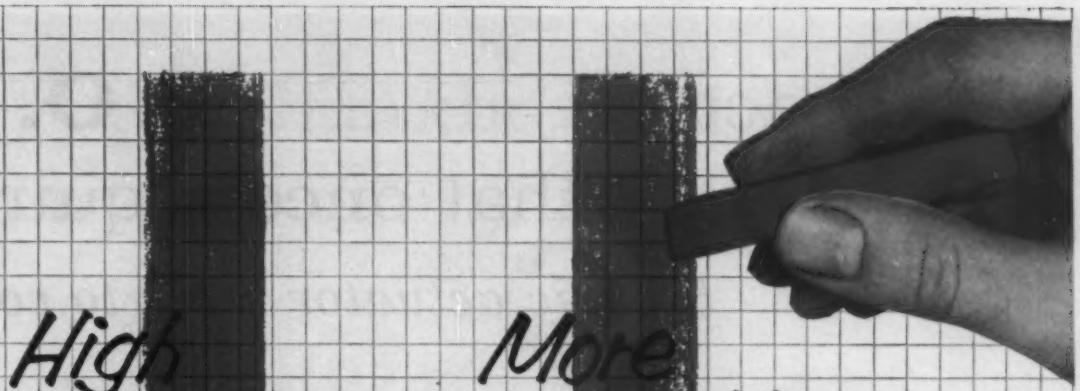
GENERAL PRECISION EQUIPMENT CORPORATION GPE

A subsidiary of General Precision Equipment Corporation

2600 Eighth Street, Berkeley, California

Branch offices and representatives in principal cities

4608



High Reactivity

More Soluble Reaction Products

You get BOTH in all 6 forms of

SOLVAY CAUSTIC POTASH

When you start with a more reactive material like Solvay® Caustic Potash, you usually get better results. Many users prefer it to caustic soda because it enables them to produce more soluble reaction products and less viscous solutions.

For example, its high solubility permits liquid end products having high soap concentration. Many heavy-duty liquid detergents would not exist were it not for ingredients derived from caustic potash.

Its high reactivity is also useful in mercaptan extraction and desulfurization of petroleum products. Caustic potash solutions effectively absorb carbon dioxide and hydrogen sulfide in industrial gases. Dry forms are highly hygroscopic, excellent for dehydration.

Sodium Nitrite • Calcium Chloride • Chlorine • Caustic Soda • Caustic Potash Potassium Carbonate • Sodium Bicarbonate • Chloroform • Methyl Chloride Soda Ash • Vinyl Chloride • Ammonium Chloride • Methylene Chloride • Carbon Tetrachloride • Snowflake® Crystals • Monochlorobenzene • Ortho-dichlorobenzene Para-dichlorobenzene • Ammonium Bicarbonate • Hydrogen Peroxide • Aluminum Chloride • Cleaning Compounds • Mutual® Chromium Chemicals

Allied Chemical

SOLVAY PROCESS DIVISION
61 Broadway, New York 6, N. Y.

SOLVAY branch offices and dealers are located in major centers from coast to coast.

—Mail the coupon for samples and *new* Solvay Technical Bulletin crammed with facts, tables, diagrams for applying caustic potash.

SOLVAY PROCESS DIVISION ED-99
ALLIED CHEMICAL CORPORATION
61 Broadway, New York 6, N. Y.

Please send me without cost:

Samples of Technical Grade Caustic Potash
☐ Flake ☐ Small Flake ☐ Solid
☐ Ground ☐ Liquid, 45% strength
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Samples of Mercury Cell Caustic Potash
☐ Flake ☐ Liquid, 45% strength

☐ New Technical Bulletin 15, Caustic Potash

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For more data on advertised products, use Readers' Service Cards, last page.

Compact FISHER P.O.P. that once required *5 basic actuator sizes to cover*

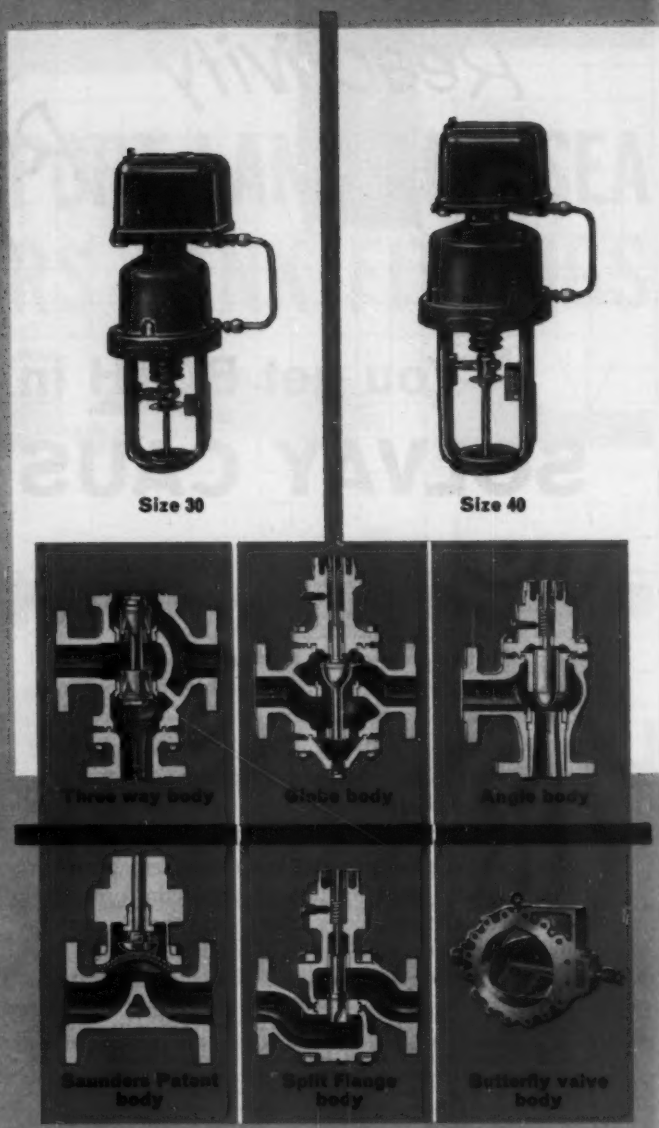
FISHER
SERIES
470 P.O.P.
PNEUMATICALLY OPERATED PISTON

Power: Delivers same power in either direction at any point of the stroke.

Speed: For example, the size 60 gives you 1.5"/sec. stroking speed.

Accuracy: Max. Hysteresis—0.15% of stroke or signal.
Repeatability—0.08% of stroke or signal.
Resolution Sensitivity—0.02% of instrument pressure range.

Only Fisher gives you this wide selection of actuator-body combinations. This small, compact piston actuator incorporates its own positioner mounted integrally on top of the cylinder. Positioner receives any of the normally used pneumatic instrument signals. Then, without an air set, actuator utilizes the full potential of the available instrument air or gas supply (up to 150 psi) to provide exceptional speed and power. Easily reversible actuator can be changed in the field. Also available in spring return and side mounted handjack models. Send for free booklet E-470.

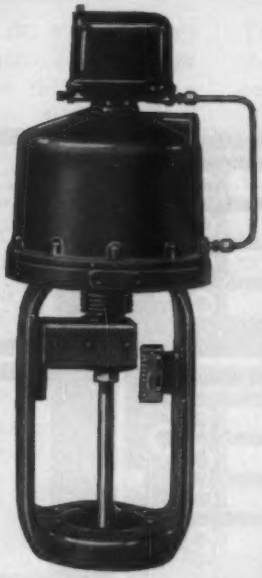


IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD . . . CHANCES ARE IT'S CONTROLLED BY . . .

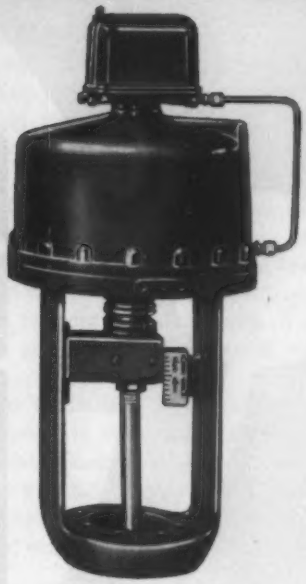
actuators handle difficult jobs giant-size equipment

all body styles and sizes

Size 60



Size 80

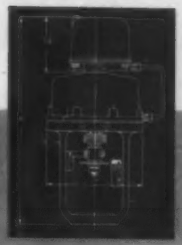


Size 100

SPECIFICATIONS

Actuator Size	Cylinder Size, Inches	Stem Size, Inches	Body Size, Inches	AVAILABLE STEM FORCE		Travel, Inches
				100 PSI Supply	150 PSI Supply	
30	4¾	⅜	½-1½	1500	—	⅜-¾
40	6⅛	½	2-4	2500	—	¾-1½
43	4¾	½	2-4	1500	2200	⅜-1½
60	8½	¾	5-8	5000	—	⅜-2
63	4¾	¾	5-8	1500	2200	⅜-2
64	6⅛	¾	5-8	2500	3600	⅜-2
80	10¾	1	10-16	8000	—	¾-3
100	13	1¼	10-16	12000	—	¾-3

Note 1. Sizes 43, 63 and 64 may use supply pressure up to 150 psi.

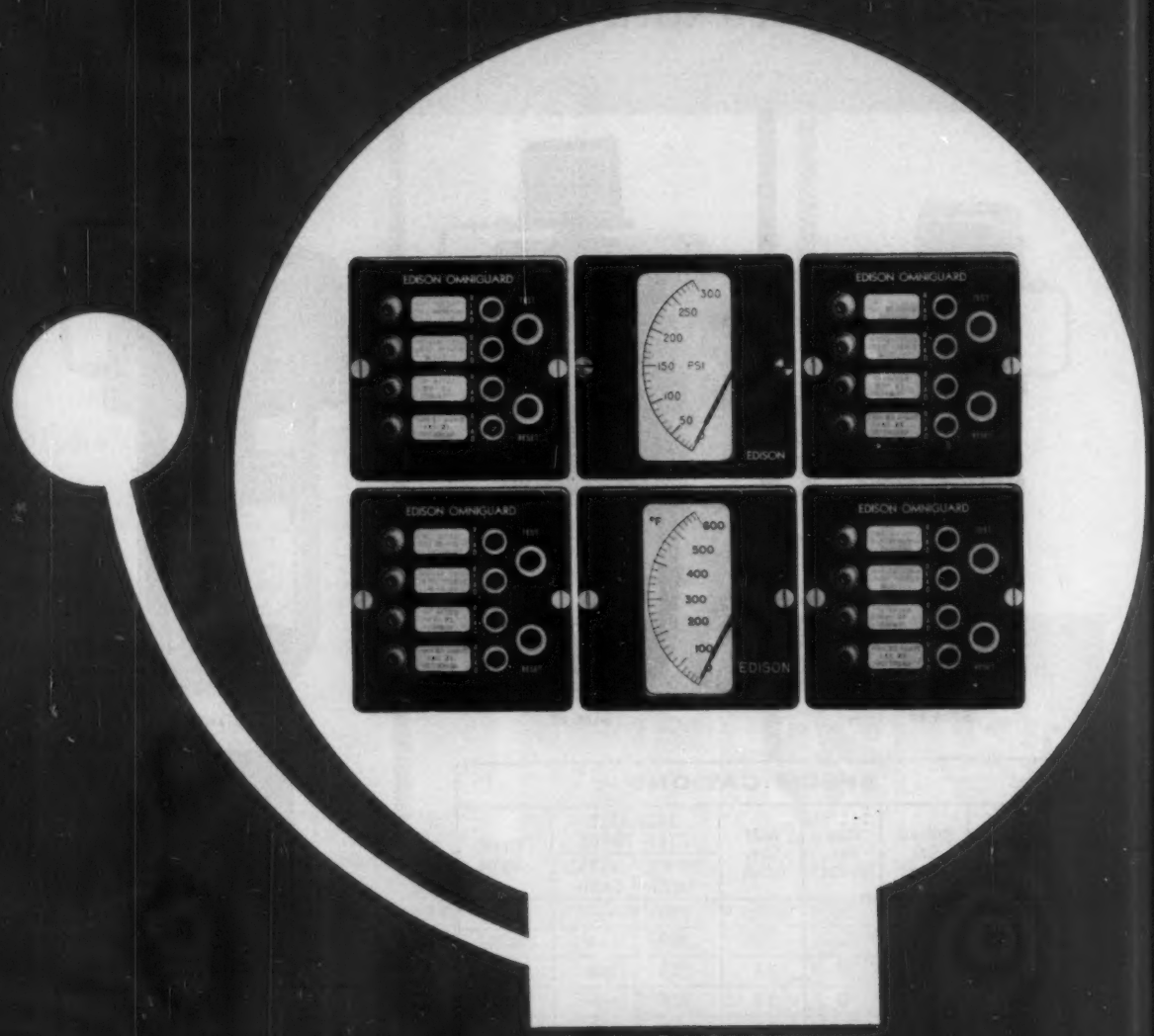


Actuator Size	B Inches	C Inches
30	19¼	6¾
40	21⅝	8⅛
60	23⅛	10½
80	33 1⁄16	12¾
100	33 1⁄16	15

FISHER® Controls
SINCE 1880

FISHER GOVERNOR COMPANY
Marshalltown, Iowa / Woodstock, Ontario / London, England
BUTTERFLY VALVE DIVISION: CONTINENTAL EQUIPMENT CO., CORAOPOLIS, PENNSYLVANIA

For more data on advertised products, use Readers' Service Cards, last page.


EDISON OMNIGUARD
300
250
200
150 PSI
100
50
EDISON
EDISON OMNIGUARD
EDISON OMNIGUARD
°F
600
500
400
300
200
100
EDISON
EDISON OMNIGUARD

GUARD ALL CRITICAL PRESSURES AND TEMPERATURES WITH . . .

THOMAS A. EDISON LOW-COST, OMNIGUARD WARNING SYSTEM

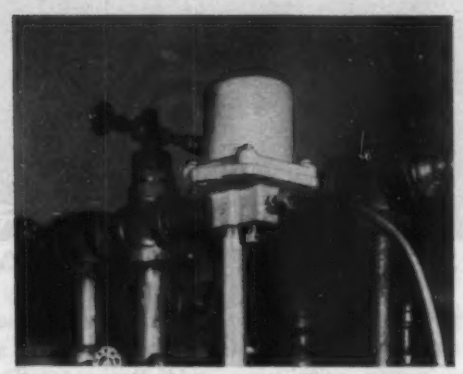
Here is a versatile, highly-reliable continuous warning and monitoring system. By simply pushing a button on this panel you obtain a reading of *key pressure* and *temperature* points throughout your plant. In addition, this system provides instantaneous warning when pressure or temperature deviates from pre-set limits.

PRESSURE With the Edison Omniguard system you can monitor gas, fluid or vapor pressure. Heart of the system is a rugged accurate pressure detector which converts pressure directly to electrical resistance—requires no milli-volt conversion—no amplifier. For pressures under 60 PSI a precision capsule is the sensing element. From 60 to 3000 PSI special burdon tube elements are used.

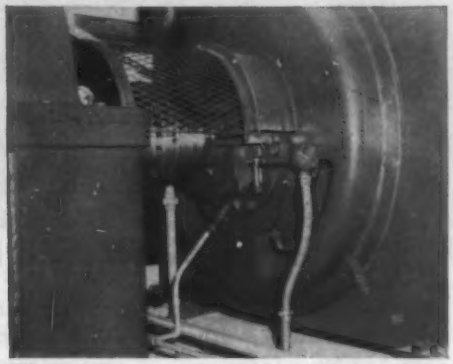
When pressure changes, resistance varies and this deviation is transmitted to the control panel. Units operate over ambient temperatures of 32° to 150°F. Control panels are available with a wide variety of scales and are equipped with both normally open and normally closed alarm contacts to operate any type of auxiliary device or to automatically shut down machinery or process.

TEMPERATURE Edison Omniguard also provides reliable protection from overheating. You can monitor the temperature of bearings, gases and liquids in critical equipments or processes. Reliable Edison Resistance Temperature Detectors have no moving parts and give instantaneous warning when limits are exceeded. Unlike other systems which only scan, Omniguard is continuously monitoring. You can obtain exact readings of temperatures in all parts of your plant from one central control panel.

For greater flexibility and reliability each detector circuit is completely independent. If one circuit is damaged, all other circuits remain "on guard." When changes or additions are required they can be accomplished quickly and easily.



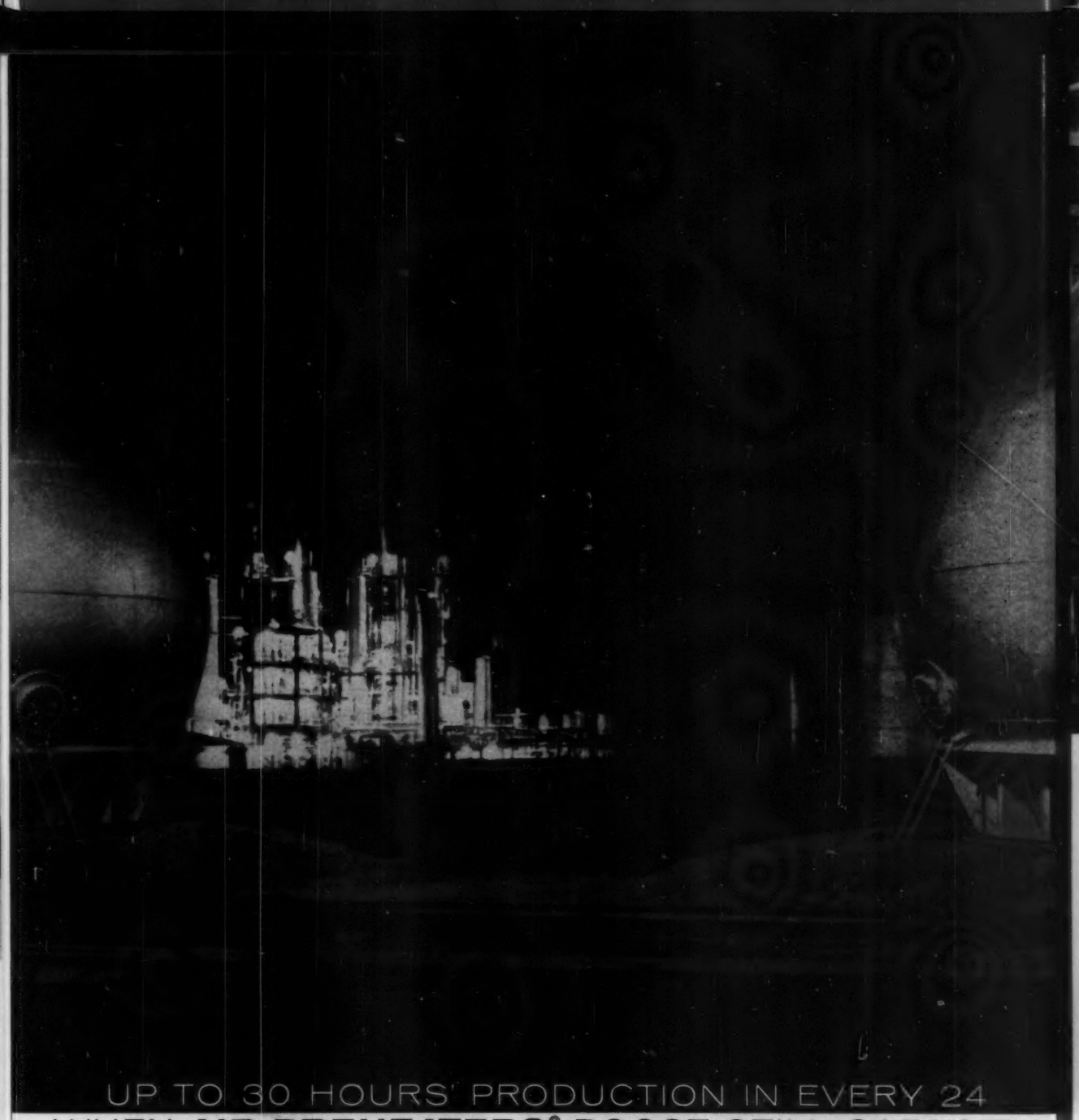
Compact, reliable Resistance Pressure Detector transmits changes in pressure to central control panel.



Rugged, accurate Resistance Temperature Detector guards against overheating of this motor bearing.

Thomas A. Edison Industries
INSTRUMENT DIVISION
96 LAKESIDE AVENUE, WEST ORANGE, N. J.

McGRAW EDISON



UP TO 30 HOURS' PRODUCTION IN EVERY 24
WHEN **AIR PREHEATERS**® BOOST STILL CAPACITY

You can boost the capacity of your stills by as much as 25% with a Ljungstrom Air Preheater, because an Air Preheater can recover as much as 1000°F from the still exhaust and put this recovered heat back into the combustion air. As a result your fuel burns more completely, at higher temperatures — and you get more product from every hour of still operation.

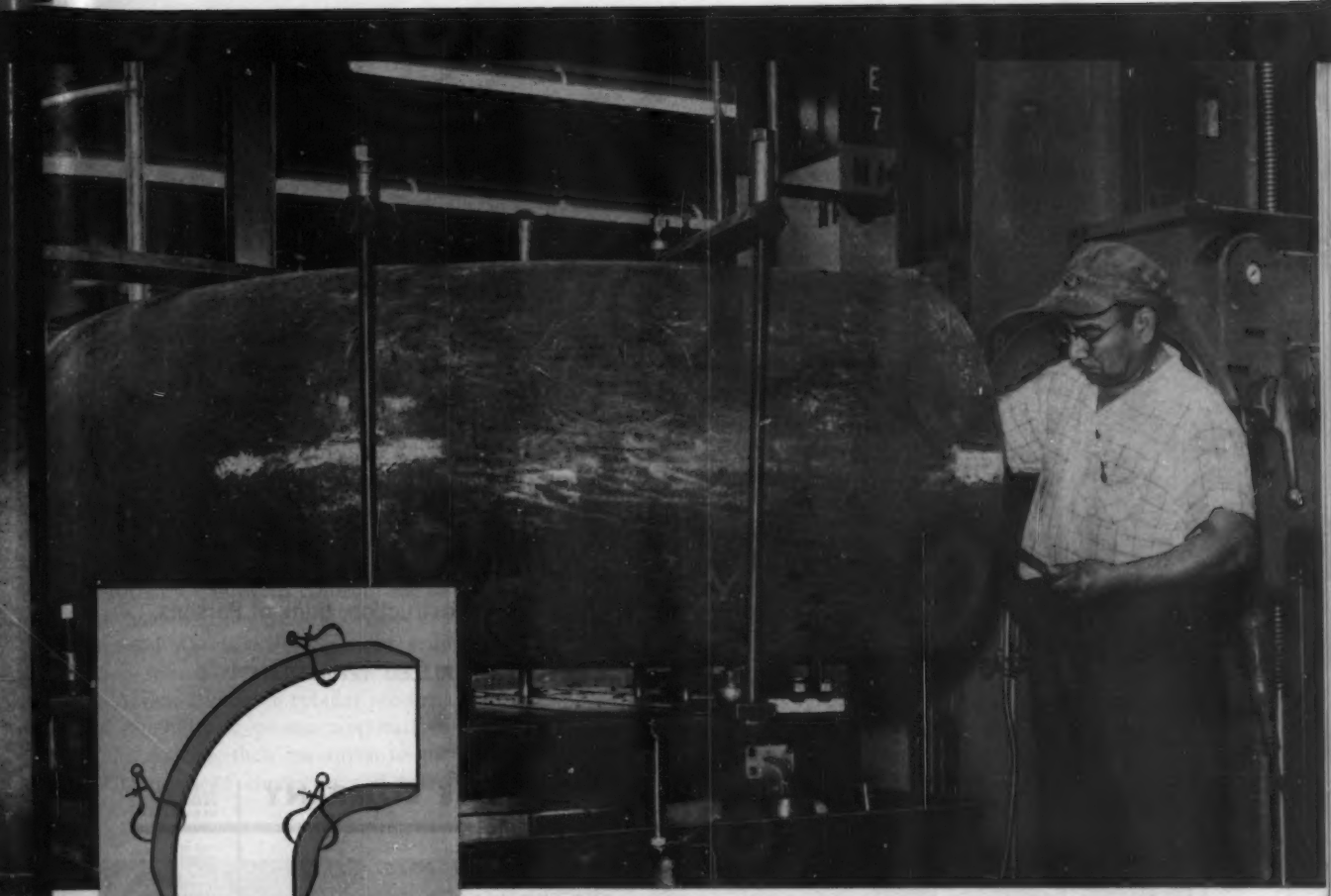
Equipment availability improves with an Air Preheater, too. There's less slag, fewer deposits when fuel burns in preheated air. Oil tubes stay clean, stills stay on-stream months longer, with less downtime for routine maintenance.

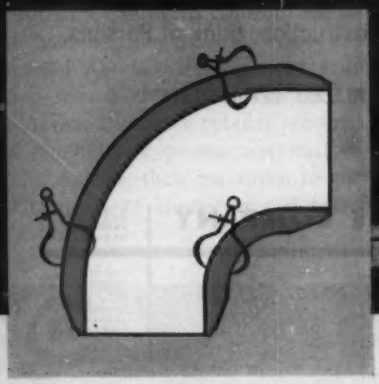
Air Preheater saves money other ways, too. If you're refining corrosive crudes or operating stills at very high temperatures, consider replacing all or a part of your convection surfaces with an Air Preheater. That way you minimize your need for expensive heat- and corrosion-resistant alloys, and get up to 25% savings on fuel bills.

One company's fuel savings with a Ljungstrom Air Preheater are factually described in a published magazine article by O. F. Campbell. Write today for your free copy to The Air Preheater Corporation, at the address below.

THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N. Y.





Uniform Wall Elbows

Key-Kast Elbows have cast steel walls of a uniform thickness approximately 15% heavier than the required minimum thickness of pipe walls of the same I.D. For extra highly stressed line sections, the wall thickness and strength can be increased as much as desired — without sacrificing uniformity.

The flexibility of Key-Kast Elbows permit their use in piping systems based on the usual piping stress calculations. Write for engineering bulletin entitled **"Key-Kast Welding Elbows in Piping Stress Calculations."**

Products of W-K-M's *Creative Engineering*

Key-Kast Fittings can handle any piping job. Specify them. You'll get outstanding service.

KEY-KAST®—the only cast elbows that meet all requirements for strength and flexibility

KEY-KAST *Uniform Wall* Alloy Steel Welding Elbows will give you outstanding service in any high pressure, high temperature alloy piping application. Only Key-Kast Elbows have cast steel walls of uniform thickness and strength — the most important factor in selecting the right fittings for your job.

Quality controlled through rigid metallurgical standards, Key-Kast Fittings meet ASTM specifications, and ASME and ASA code requirements. Specialists in fluid flow design these fittings to move your lading more safely and efficiently.

Call your Key-Kast representative for prompt, experienced service in selecting the Key-Kast Fitting best for you. Available in all standard shapes, sizes and schedules . . . or specially designed to meet specific conditions of pressure, temperature and lading. *W-K-M Division of ACF Industries, Incorporated, P. O. Box 2117, Houston, Texas.*

W-K-M 40 YEARS
SERVING INDUSTRY
DIVISION OF ACF INDUSTRIES INCORPORATED

In Petroleum and Chemical Engineering

PARSONS

means "Specialized Versatility"

Repeat business has played a vital role in establishing Parsons as a leader in the engineering-construction field. Satisfaction with Parsons' performance, on all kinds of petroleum and chemical facilities, has brought repeat assignments on job after job—time after time. When you think of engineering or construction, think of Parsons, and you too will realize that

PARSONS MEANS "SPECIALIZED VERSATILITY"

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For more data on advertised products, use Readers' Service Cards, last page.

See why ALCOA ALUMINUM makes a good design habit

Requirement: low-cost, high-strength, corrosion-resistant process pipe and tubing

Key to good design: specify tubular products of Alcoa Aluminum

Metal tube or pipe is perhaps the most common material to be found in chemical and petroleum processes. It carries process liquids and gases through each stage of production. It serves in instrumentation lines, relaying information between controls and valves. It is the heart of heat exchangers and other processing equipment. Specify ALCOA® Aluminum Pipe and Tube to do all these jobs safely and economically.

ALCOA aluminum tubular products have a long record of reliability in process applications. No other pipe or tube matches their resistance to corrosion from such a wide range of chemicals and petroleum products. No other metal approaches their low cost and freedom from maintenance. No other tube or pipe combines these features with long life, high strength, and the physical properties required by so many processors.

These pages show you just a few of the applications where ALCOA aluminum tubular products are at work fighting corrosion and providing substantial economies. There is an area in your process where aluminum can help cut costs and improve efficiency. ALCOA makes aluminum pipe and tube in a number of standard alloys and in a wide variety of sizes ideally suited to chemical and petroleum processing.

For more data on advertised products, use Readers' Service Cards, last page.

ALCOA ALUMINUM

ALUMINUM COMPANY OF AMERICA

Piping

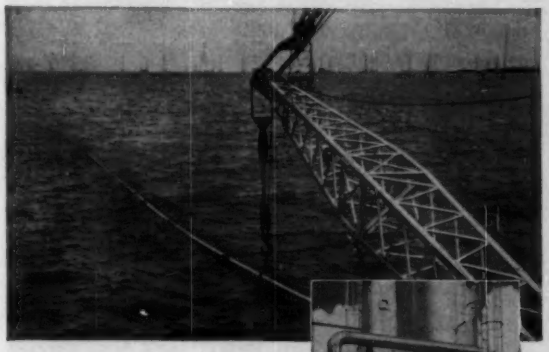
Where product protection, corrosion resistance and strength are primary considerations for piping, aluminum is your best answer, and is often the least expensive.

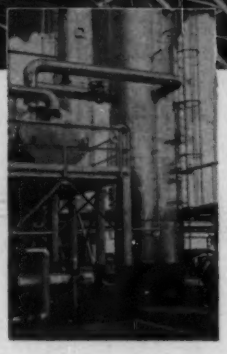
ALCOA Aluminum Piping resists attack by materials within the pipe, as well as by corrosive environments outside. It does not catalyze the decomposition of many sensitive chemicals as other metals do.

With ALCOA Aluminum Pipe you also get a smooth, low-friction surface, high thermal conductivity and nonsparking characteristics . . . all highly desirable qualities.

In ultra-low temperature applications ALCOA Aluminum Piping retains its excellent physical properties without embrittlement. Tests to as low as minus 423 degrees F show it actually increases in strength as the temperature drops. That's why aluminum is specified for tonnage oxygen and other cryogenic applications.

ALCOA Aluminum Pipe is produced in ASA sizes from ⅛ in. through 12 in., and in a variety of alloys and tempers, some with the strength of low carbon steel. Seamless pipe in sizes up to 20 in. in diameter is available.





A welded section of 4-in. Alcoa Aluminum Pipe is lowered into Lake Maracaibo, Venezuela, for the world's first permanent aluminum underwater oil pipeline. It replaces a steel pipeline that failed from the corrosive effects of the lake's brackish waters. The line connects an underwater well to a flow station.

Because aluminum piping does not discolor or contaminate the product, it is used at this organic chemicals plant to handle chemicals for the production of synthetic fibers.

BURSTING PRESSURES Pipe—not welded

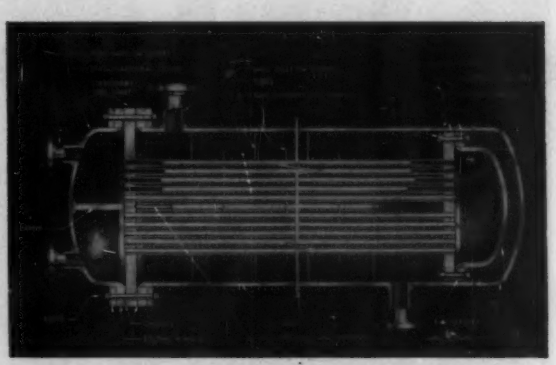
Nominal Pipe Size, Inches	Schedule Number	BURSTING PRESSURE, PSI			Nominal Pipe Size, Inches	Schedule Number	BURSTING PRESSURE, PSI		
		3003-H112①	6063-T6	6061-T6			3003-H112①	6063-T6	6061-T6
⅛	40	.....	11,900	15,020	2½	5	.....	1,810	.....
¼	40	.....	11,490	14,490	2½	10	.....	2,650	.....
⅜	40	.....	9,270	11,730	2½	40	1,790	4,590	5,820
½	40	.....	8,860	11,220	3	5	.....	1,480	.....
¾	10	.....	5,160	.....	3	10	.....	2,160	.....
¾	40	.....	7,220	9,130	3	40	1,560	3,980	5,050
1	5	.....	3,160	.....	3½	40	1,420	3,630	4,600
1	10	.....	5,450	.....	4	5	.....	1,150	.....
1	40	2,630	6,750	8,560	4	10	.....	1,670	.....
1¼	5	.....	2,480	.....	4	40	1,320	3,370	4,280
1¼	10	.....	4,250	.....	5	40	1,150	2,950	3,750
1¼	40	2,160	5,550	7,030	6	5	.....	1,180	.....
1½	5	.....	2,160	.....	6	40	1,090	2,680	3,410
1½	10	.....	3,690	.....	8 (.277)	20	790	2,020	2,560
1½	40	1,940	4,990	6,330	8 (.322)	40	920	2,360	2,990
2	5	.....	1,720	.....	10 (.279)	...	630	1,630	2,070
2	10	.....	2,920	.....	10 (.307)	30	700	1,790	2,280
2	40	1,630	4,190	5,320	10 (.365)	40	835	2,140	2,720
					12 (.375)	...	720	1,850	2,340

Computed bursting and yielding pressures and conversion factors for 3003-H112 alloy also apply to 3003-F alloy. They are based on the properties of the 3003-O alloy.

Heat exchanger tubing

Corrosion resistance, long life, product purity, high thermal conductivity and economy . . . all these vital requirements in heat exchanger design are satisfied when you specify ALCOA Aluminum Tubing. The petroleum industry uses aluminum in main column overhead condensers where its freedom from fouling and excellent heat transfer properties have made it a natural selection. Heat exchangers with ALCOA Aluminum Tubing also are used in the chemical process industry. Prime examples are for the production of ammonia, nitric acid, vegetable oils, naval stores, naphthalene, hydrogen peroxide, oxygen and urea. These and other processes call for heat exchanger tubing with high strength, excellent sub-zero physical properties, high thermal conductivity, or nontoxicity and noncatalytic properties. Any one or a combination of these requirements can be met efficiently and economically with ALCOA Aluminum Tubing.

ALCOA Aluminum is the least expensive tube available. In the common sizes it costs one-third less than mild steel, one-half as much as admiralty, and only one-fifth as much as stainless.



For certain processes where corrosive or sensitive materials are involved it is often advisable to use aluminum for entire heat exchanger systems to avoid system corrosion and contamination of the product. A typical heat exchanger is shown here. Alloy recommendations are given in "Alcoa Aluminum Heat Exchanger Tubes."

A Midwest utility saved 50 per cent on tubing costs by using Alcoa Aluminum instead of admiralty for tubing in this surface condenser. Successful operation of this unit has led to installation of similar units by other utilities. This use demonstrates aluminum's economy and superior resistance to ammonia, carbon dioxide and hydrogen sulfide.

See why ALCOA ALUMINUM makes a good design habit

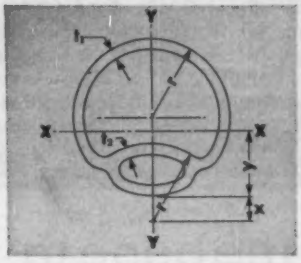
Unitrace the aluminum process pipe with integral steam tracing

ALCOA® Unitrace solves the problem of applying heat to a product during processing. With Unitrace you get standard pipe OD with an integral steam passage located adjacent to the product passage . . . eliminating the labor and cost involved in installing external steam jackets or steam tracer tubes.

Extruded as a single unit of ALCOA 6063-T5 aluminum alloy, Unitrace has aluminum's natural corrosion resistance, making it ideal for transferring molten sulfur, ammonium nitrate solutions, glacial acetic acid, fatty acids, naphthalene, phthalic anhydride, urea, wax, tar products, and numerous other products which must remain liquid during transfer.

ALCOA continues to be the leader in supplying various sizes of this type of pipe. You can get Unitrace in pipe sizes from 1 in. through 8 in.

Because Unitrace is completely compatible with other piping systems, it provides an unusual degree of design flexibility in process systems. Special Unitrace flanges, tracecaps, elbows and adapter flanges, cast of ALCOA A356-T7 aluminum alloy, are available from ALCOA.



	Unitrace Sizes	1 in.	1½ in.	2 in.	3 in.	4 in.	6 in.	8 in.
Axis XX	Moment of Inertia (I) in.⁴	.09	.34	.72	2.71	6.52	31.82	81.82
	Radius of Gyration (R) in.	.37	.58	.72	1.09	1.42	2.12	2.78
	Section Modulus (S) in.³	.13	.34	.56	1.42	2.65	8.73	17.22
Axis YY	Moment of Inertia (I) in.⁴	.09	.33	.70	2.65	6.36	29.72	76.70
	Radius of Gyration (R) in.	.37	.67	.71	1.08	1.40	2.08	2.69
	Section Modulus (S) in.³	.14	.34	.89	1.52	2.83	8.97	17.79

Sizes	1 in.	1½ in.	2 in.	3 in.	4 in.	6 in.	8 in.
r	.657	.950	1.187	1.750	2.250	3.312	4.312
t_1	.133	.148	.154	.170	.187	.280	.322
t_2	.145	.163	.174	.185	.200	.307	.354
x	.133	.344	.406	.625	.813	1.500	2.000
y	.61	.87	1.08	1.59	2.03	2.98	3.87

Average coefficient of thermal expansion (per °F)	—58 to +68°F	68 to 212°F	68 to 392°F	68 to 572°F
	12.1 x 10⁻⁶	13.0 x 10⁻⁶	13.6 x 10⁻⁶	14.2 x 10⁻⁶

Temp. °F	Pressure psi	1 in.	1½ in.	2 in.	3 in.	4 in.	6 in.	8 in.
Up to 100°F	Bursting Pressure of Product Line	2980	2265	1925	1425	1210	1210	1085
	*Pressure Differential	2240	1700	1445	1070	910	910	815
	Bursting Pressure of Trace Line	2980	2265	1925	1425	1210	1210	1085
200°F	Bursting Pressure of Product Line	2800	2130	1810	1340	1140	1140	1020
	*Pressure Differential	2100	1600	1360	1005	855	855	765
	Bursting Pressure of Trace Line	2800	2130	1810	1340	1140	1140	1020
300°F	Bursting Pressure of Product Line	2530	1920	1630	1210	1030	1030	925
	*Pressure Differential	1860	1410	1200	900	755	755	675
	Bursting Pressure of Trace Line	2530	1920	1630	1210	1030	1030	925
400°F	Bursting Pressure of Product Line	1340	1020	865	650	545	545	490
	*Pressure Differential	670	510	435	320	275	275	245
	Bursting Pressure of Trace Line	1340	1020	865	650	545	545	490

*The pressure in the product line should not exceed the pressure in the trace by more than this amount.
Note: Bursting pressure data based on tests with welded Unitrace flanges and minimum mechanical properties.

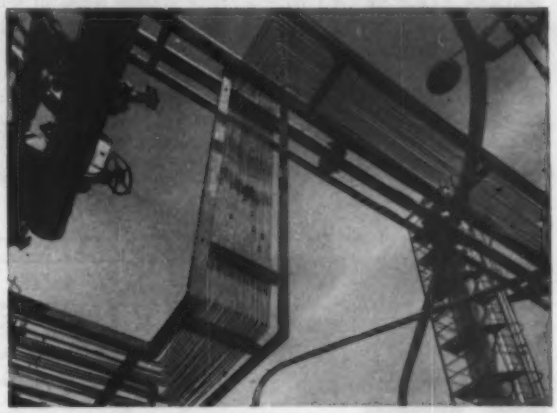
Utilitube for instrument, hydraulic, fuel and lubricating lines

Utilitube is a low-cost coiled tube made of 5050 aluminum alloy. Literally millions of feet of it have been installed for the above applications. For these and other uses Utilitube provides outstanding economy along with such desirable physical properties as corrosion resistance, freedom from gum or sludge formation, high fatigue strength, good bursting strength and easy workability.

Utilitube can be supplied in economical, long lengths up to 1,000 feet or more. It weighs only one-third as much as copper tubing of similar capacity and costs up to 40 per cent less.

Utilitube can be joined by all common methods. Standard compression-type or flare-type fittings may be used. Utilitube can be flared easily, using conventional tools and practices. Installation methods are similar to those used with other types of tubing.

Gas and oil processing plants use large quantities of Alcoa Utilitube for instrument air lines. The corrosive atmospheres of hydrogen sulfide and sulfur dioxide in these areas have no effect on Utilitube. In addition to its resistance to corrosion, Utilitube has superior physical properties at sub-zero temperatures. That's why more and more of it is being used for cryogenic processes. In this application, its physical properties actually improve as the temperature drops.



BURSTING PRESSURES AND WEIGHTS PER FOOT OF TYPICAL SIZES OF ALCOA UTILITUBE①

Computed Bursting Pressures based on minimum properties at operating temperatures not exceeding 100°F.

OD, in.	Wall Thickness in.	Computed Bursting Strength②, psi	Weight per Foot③, lb
⅛	0.025	7380	0.0091
3/16	0.028	5260	0.0163
¼	0.032	4420	0.0255
5/16	0.035	3810	0.0355
⅜	0.049	4520	0.0584
⅜	0.035	3130	0.0435
½	0.049	3300	0.0808
½	0.035	2300	0.0595
⅝	0.049	2590	0.1032
¾	0.058	2550	0.1468

① B50S-O

② $P=KS\frac{2t}{D-0.8t}$ in which S=18,000 psi specified minimum longitudinal tensile strength, D=nominal outside diameter in inches, t=nominal thickness in inches, and K is a factor dependent on yield-tensile strength ratio (K=0.86 for B50S-O).

③ Based on 0.097 lb per cu in., from "Alcoa Aluminum and Its Alloys," 1950, page 108, Table 13.

For more data on advertised products, use Readers' Service Cards, last page.

Pipe jacketing

Pipe jacketing made with ALCOA Aluminum Foil or sheet protects insulated process pipes both indoors and outdoors. In many cases it actually costs less to cover pipes with this material than it does to paint them. Aluminum pipe jacketing has required no maintenance for as long as 10 years in some applications. This jacketing resists corrosion and can be used with a moisture barrier over any type of insulation. It is available with or without a moisture barrier attached.

Aluminum jacketing is easy to cut and handle, and can be installed quickly and easily without special tools or skills.

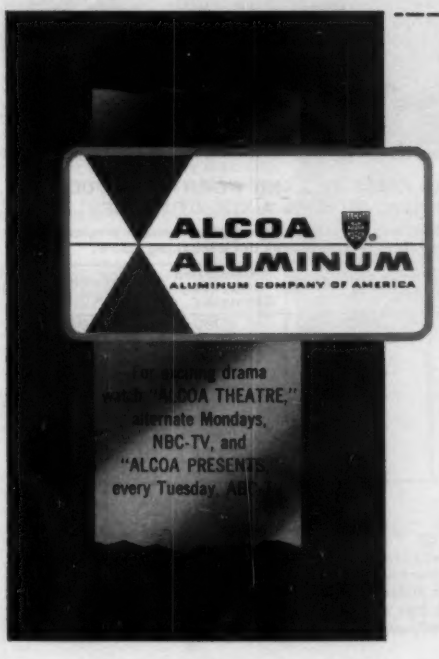
UNISTRENGTH Pipe newest tubular product of Alcoa Aluminum

ALCOA developed this new type of aluminum pipe to make possible welded lines with uniform bending, bursting and tensile strength throughout. The secret of UNISTRENGTH is a reduction in wall thickness everywhere but at the ends where it is needed for joining. This compensates for the local reduction in strength caused by the heat of welding on popular heat-treatable pipe alloys. Result: ALCOA eliminates unneeded metal (up to 40 per cent) to provide a uniformly strong piping system with important savings in weight and cost.

ALCOA ENGINEERS have worked closely with all segments of the process industries for over 40 years, and can help you specify the aluminum tubular product best suited for your process application. ALCOA's unparalleled experience in this field is available to you for the asking. Write to the address below, stating your requirements as specifically as possible. ALCOA's development engineers will welcome the opportunity to work with you on your problems.

You can also take advantage of the wide selection of free ALCOA literature on aluminum tubular products and other process applications. Simply check the booklets you want on the coupon and mail to the address below. ALCOA will forward your material promptly and without obligation.

During 1959, ALCOA will conduct engineering conferences in a number of major cities on process industries uses of aluminum. Call your nearest ALCOA sales office for details.



Aluminum Company of America, 874-J Alcoa Building, Pittsburgh 19, Pa.

Please send me the following literature covering Alcoa Aluminum for tubular products and other uses in the process industries:

- ☐ 10197 Aluminum Pipe and Fittings
- ☐ 34-10418 Alcoa Unitrace: Combines Piping and Tracing in One Unit
- ☐ 10186 Alcoa Aluminum Heat Exchanger Tubes
- ☐ 10270 Alcoa Utilitube
- ☐ GL88C Aluminum Pipe for Aircraft Fuel
- ☐ 10460 Process Industries Applications of Alcoa Aluminum
- ☐ 10508 Cleaning and Maintenance
- ☐ 20849 Resistance of Aluminum Alloys to Weathering and Resistance of Aluminum Alloys to Chemically Contaminated Atmospheres
- ☐ 20265 Have You Tried Aluminum in Your Refinery?
- ☐ 20935 Designing to Prevent Corrosion
- ☐ GL86C Unfired Pressure Vessels of Aluminum Alloys
- ☐ GL149 Welded Aluminum Gas Cylinders ICC Approved
- ☐ 20437 Aluminum Alloy Heat Exchangers in the Process Industries
- ☐ DD508 Aluminum Alloys in Tank Trucks and Tank Trailers
- ☐ 10387 Alcoa Standard Storage Tanks
- ☐ 20272 Aluminum Alloys for Handling High Purity Water
- ☐ 20268 Resistance of Aluminum Alloys to Fresh Waters
- ☐ 10130 Forming Alcoa Aluminum
- ☐ 10416 Brazing Alcoa Aluminum
- ☐ 10415 Welding Alcoa Aluminum
- ☐ 10051 Alcoa Aluminum Handbook

Name_____

Company_____

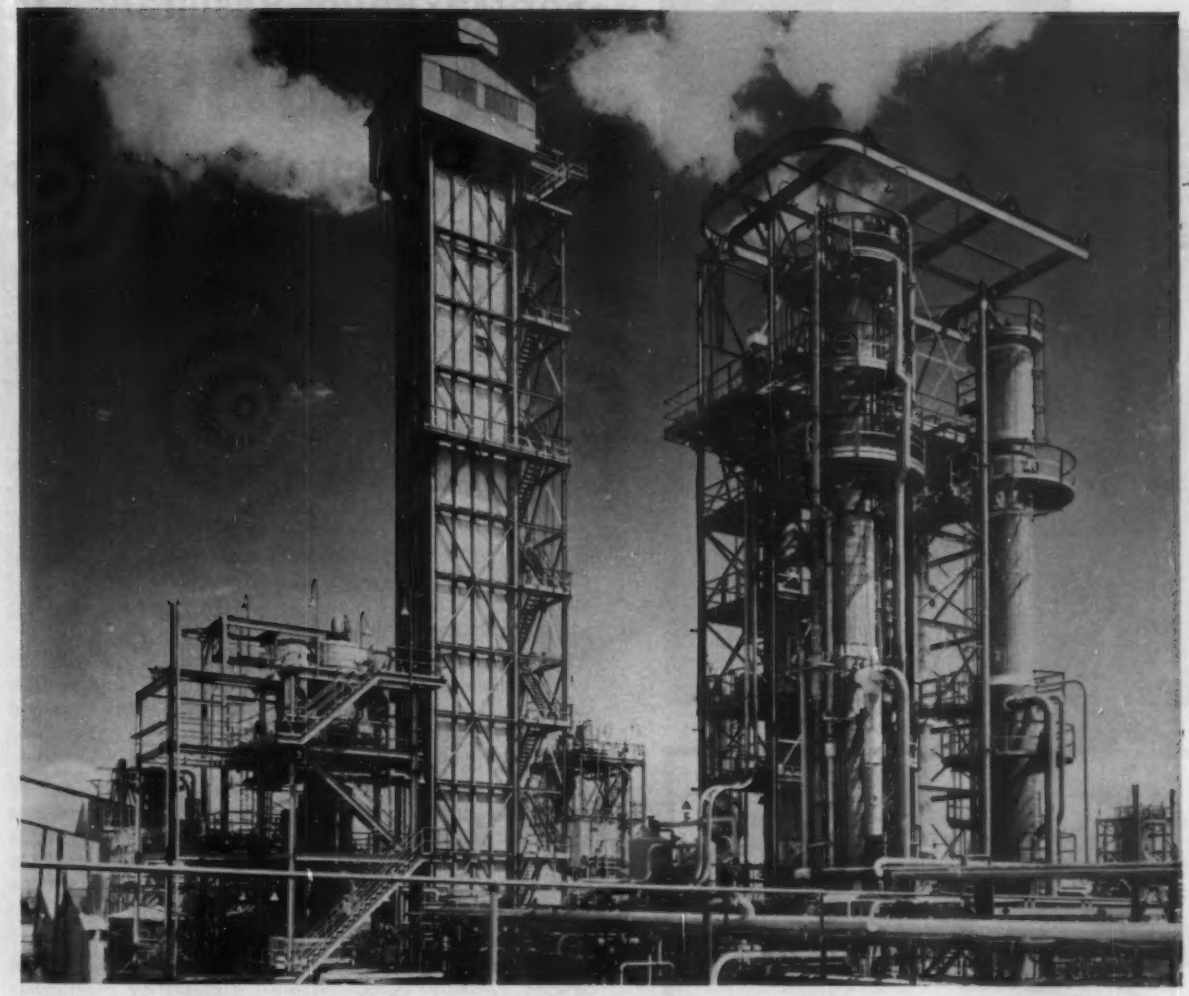
Title_____

Address_____

City_____

State_____

For more data on advertised products, use Readers' Service Cards, last page.



A precedent-setting new concept in engineering service

The Pechiney-Grace Urea Process by Foster Wheeler

Now Pechiney's basic urea synthesis, Grace's operating experience and Foster Wheeler's engineering design and construction experience are available as a totally new packaged service to licensees.

It's a unique package, giving you:

- a total recycle process covered by one licensing agreement, from feed end through finishing operations, yielding urea of the highest purity.
- the benefits of experience gained by W. R. Grace in modifying and improving the original Pechiney Process and operating a full-scale plant for four years.
- Foster Wheeler's experience in originally bringing the Pechiney Process from pilot plant to full-scale commercial operation, and working with Grace engineers on subsequent improvements which created the Pechiney-Grace Process.

The new license package also makes available for the first time a new ammonia recovery system—currently saving 10-15 tons a day for Grace, and a highly efficient purification system. For information write to: *Foster Wheeler Corporation, 666 Fifth Avenue, New York 19, N. Y.*

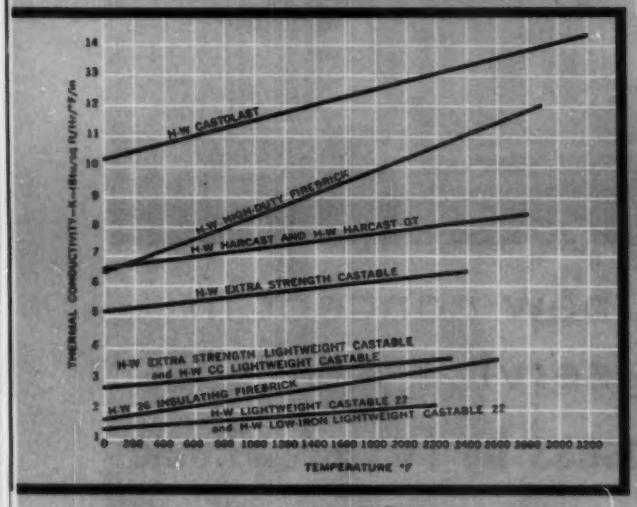
FOSTER WHEELER

NEW YORK LONDON PARIS ST. CATHARINES, ONT.

For Maximum Resistance to

HARBISON-

for every petroleum refining


THERMAL CONDUCTIVITY—K=(Btu/sq ft/hr/°F/in
H-W CASTOLAST
H-W HIGH-DUTY FIREBRICK
H-W HARCAST AND H-W HARCAST GT
H-W EXTRA STRENGTH CASTABLE
H-W EXTRA STRENGTH LIGHTWEIGHT CASTABLE and H-W CC LIGHTWEIGHT CASTABLE
H-W 26 INSULATING FIREBRICK
H-W LIGHTWEIGHT CASTABLE 22 and H-W LOW-IRON LIGHTWEIGHT CASTABLE 22
TEMPERATURE °F

This Useful Chart—indicating service limits and comparative thermal conductivities (along with a table of physical properties)—is included in a newly-published brochure, "Harbison-Walker Refractories for the Petroleum Refining and Petrochemical Industries."

H-W CASTABLE REFRACTORIES

They comprise all commercial classes. Proper brand selection provides the best combination of physical and chemical properties for specific applications—assuring maximum life and economy. Installation may be by various methods—gunning, trowelling, pouring or tamping—depending upon composition and application.

H-W CASTOLAST

This extremely high-purity, low-iron castable consists of accurately grain-aized tabular alumina and low-iron calcium-aluminate binder. It develops high strength throughout its temperature range, is unaffected by reducing atmospheres, and is very abrasion resistant. It is excellent for lining catalytic vessels, butadiene reactors, feed lines and cyclones.

H-W HARCHROME

This extra strength chrome-base castable with hydraulic binder takes an extremely hard, strong set. It is especially designed for maximum wear resistance in feed lines and cyclones of catalytic cracking units.

H-W EXTRA STRENGTH CASTABLE

A blended mixture of carefully sized hard-fired refractory aggregates, bonds and hydraulic binders, this product is strongest of all regular fireclay castables. It is highly recommended for regenerator and reactor linings, catalyst feed lines, cyclones, doors and sub-bottoms of various types of furnaces, and patching worn brickwork.

H-W HARCAST AND H-W HARCAST GT

These castables are manufactured from super-duty calcined fireclay carefully combined with high-purity plasticizers and hydraulic binders. The iron content in each is less than 1%, which adequately meets the specifications of petroleum companies. They are used where platinum catalysts are employed and provide exceptional strength at all temperatures up to their service limits.

H-W LIGHTWEIGHT CASTABLE 22

(Former brand name—H-W 56 Lightweight Castable)

A quality-controlled mixture of lightweight aggregates and hydraulic binders, it combines light weight and strength to utmost degree, has very low thermal conductivity and serves as an ideal insulation behind hard surface abrasion-resistant castables or brick. It gives outstanding service in regenerators and reactor linings, ducts and breechings, boiler wall backing and tube decks, air preheater linings, heater walls, roofs and door linings.

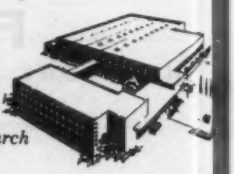
HARBISON-WALKER REFRACTORIES COMPANY

AND SUBSIDIARIES

GENERAL OFFICES: PITTSBURGH 22, PA.

World's Most Complete Refractories Service

The Garber Research Center



Leadership in refractories through constant research

Corrosion, Abrasion, Reducing Atmospheres . . .

WALKER REFRACTORIES

and petrochemical application

H-W LOW-IRON LIGHTWEIGHT CASTABLE 22

(Former brand name—H-W 56 Low-Iron Lightweight Castable)

Manufactured from low-iron lightweight aggregates and high purity calcium-aluminate binders, it is especially designed for oil refinery units operating in hydrogen and other reducing atmospheres.

H-W EXTRA STRENGTH LIGHTWEIGHT CASTABLE

(Former brand name—H-W 85 Lightweight Castable)

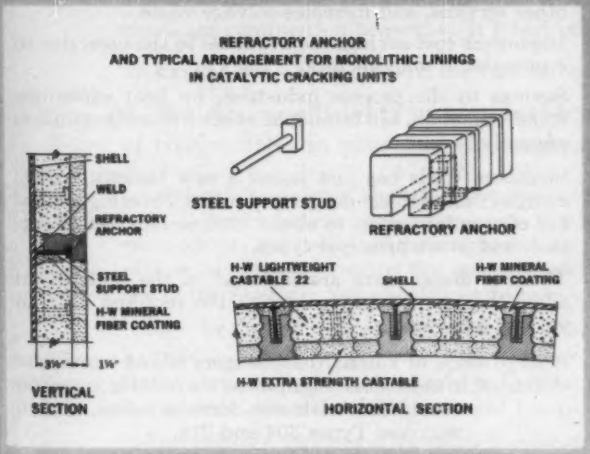
Consisting of carefully selected and sized lightweight aggregates and hydraulic setting binders, it has combined properties of light weight, high strength, low heat conductivity and desirable refractoriness. It is used for lining ducts and breechings, boiler wall backing and tube decks, furnace walls, roofs and doors.

H-W CC LIGHTWEIGHT CASTABLE

This combination of best selected and sized lightweight aggregates and hydraulic setting binders was especially developed for "one-shot" linings in catalytic cracking units.

IMPROVED ANCHORING METHOD

Supplementary to the conventional anchoring methods, the design of the refractory anchor installation shown here is particularly suitable for certain specific uses such as regenerators and reactor linings.



H-W REFRACTORY BRICK AND SHAPES

All classes of fireclay brick, high-alumina brick, silica brick, basic brick and acid-proof brick and tile are available for petroleum and petrochemical needs.

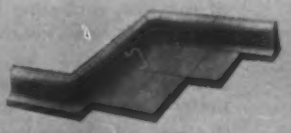
A Typical Duro Tower Packing Ring
Ring No. 403 6" x 6"

ALAMO AND VARNON

These brands possess chemical and physical properties which make them especially suited for the diversified operating conditions of refinery and petrochemical processes. Enhanced by high temperature heat treatment, VARNON has a high degree of immunity to damaging effects of carbon monoxide and hydrocarbon gases at critical temperatures.

H-W MULLITE—KORUNDAL—H-W CORUNDUM

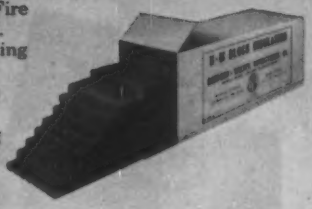
These high-alumina refractories are noted for unusual stability under severe temperature conditions, and excellent resistance to fluxing by corrosive slags and fumes, such as volatile alkalies and vanadium oxide present in the ash of some oils.



Duro Acid-proof Floor Tile

H-W INSULATING REFRACTORIES

All Classes of Insulating Fire Brick—1600°F. to 3000°F.
Mortars for Laying Insulating Brick
H-W Lightweight Castables
H-W Block Insulation
H-W Mineral Fiber Coating
H-W Finishing Cement



New Brochure

describes complete line of refractories for petroleum refining and petrochemical applications including all classes of castables, brick and shapes, insulating firebrick, block insulation, mineral fiber coating, finishing cement, and bonding mortars.

Send today for your personal copy

Harbison-Walker Refractories Company
Farmers Bank Building, Pittsburgh 22, Pennsylvania

☐ Please send me a copy of your new brochure, *Harbison-Walker Refractories for the Petroleum Refining and Petrochemical Industries.*

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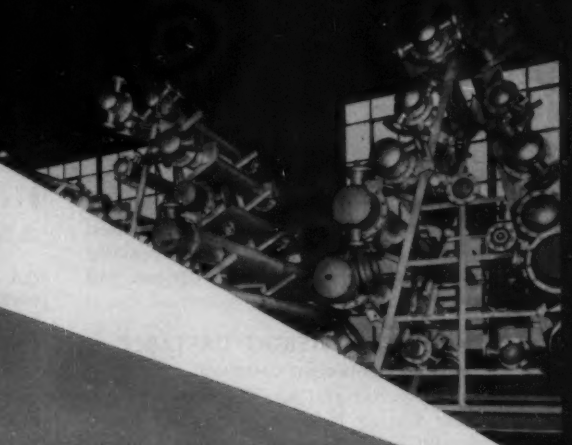
MILLIONS OF DOLLARS CAN BE SAVED



Struthers Wells

STANDARD HEAT EXCHANGERS

Standard heat exchangers are suitable for a wide range of services, including heating, cooling, vaporizing and condensing, with the maximum usefulness in the smaller sizes.

Standardization of mechanical design and price offers many important advantages to the user.

Savings may be realized in the user's engineering time, due to ease in procurement, inspection of fabrication, checking drawings and construction details.

In plant layout work, the size of the unit can be quickly established, and the complete information available allows exact details to be fixed at once.

Immediate delivery on most units often results in important savings, due to early completion of the project. Interchangeability allows reuse of the equipment in other services, and increases salvage value.

Important cost savings are available to the user, due to economies in manufacture.

Savings to the process industries, by heat exchanger standardization, are estimated at several million dollars annually.

Struthers Wells has just issued a new bulletin, giving complete mechanical design and prices, covering a number of standard sizes, to about 1200 square feet of surface, and in six principal types.

Thermal design data are included in the bulletin, to allow the user to fix the size of the required unit, in various services.

A large stock of standard exchangers allows immediate shipment, in most sizes. Equipment is available in carbon steel, also with non-ferrous tubes, and in stainless Types 304 and 316.

Complete Guide

to the selection of a standard SW Heat Exchanger is contained in Bulletin B-20. Write for your copy today

STRUTHERS WELLS PRODUCTS

PROCESSING EQUIPMENT DIVISION

Crystallizers . . . Direct Fired Heaters . . . Evaporators . . . Heat Exchangers . . . Mixing and Blending Units . . . Quick Opening Doors . . . Special Carbon and Alloy Processing Vessels . . . Synthesis Converters

BOILER DIVISION

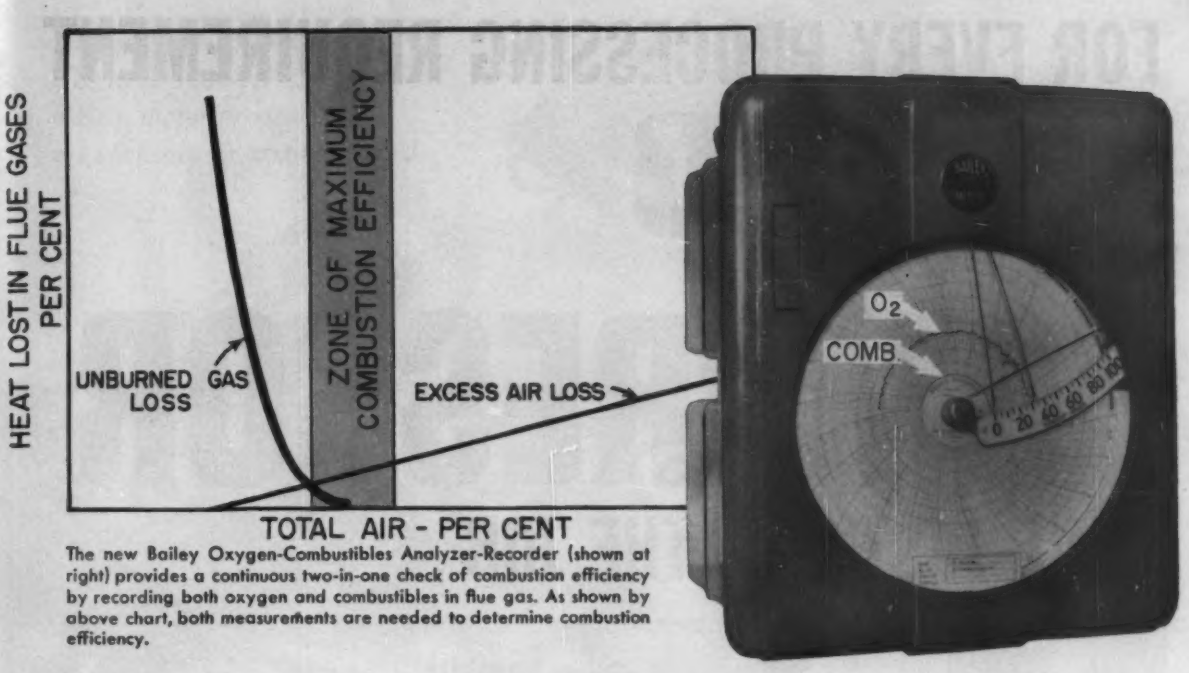
BOILERS for Power and Heat . . . High and Low Pressure . . . Water Tube . . . Fire Tube . . . Package Units

FORGE DIVISION

Crankshafts . . . Pressure Vessels . . . Hydraulic Cylinders . . . Shafting . . . Straightening and Back-up Rolls

STRUTHERS WELLS CORPORATION

WARREN, PA.



The new Bailey Oxygen-Combustibles Analyzer-Recorder (shown at right) provides a continuous two-in-one check of combustion efficiency by recording both oxygen and combustibles in flue gas. As shown by above chart, both measurements are needed to determine combustion efficiency.

BAILEY announces . . .
New 2 in 1 way to measure Heater Combustion Efficiency

The new Bailey Oxygen-Combustibles Analyzer-Recorder gives you a continuing double check on combustion economy. It's fast response measures and records:

1. Excess air—regardless of the fuel or combinations of fuels being burned.

2. The mixing efficiency of your fuel-burning equipment—by indicating the amount of combustibles in your flue gas, resulting from incomplete mixing of fuel and air.

Combustion efficiency depends upon fuel-air ratio. Too much fuel can be even more costly than too much air. And because of the interdependence of these two factors, no control that measures only one of them can give you complete protection.

Now, for the first time, you can check *both* with a *single* fast acting instrument, using the new Bailey Oxygen-Combustibles Analyzer-Recorder for industrial furnaces, kilns, heaters and boilers.

Fuel economy improves as excess air is reduced —until unburned fuel begins to show up in the flue gas. When this happens, combustion efficiency drops off sharply if there are further decreases in the air-fuel ratio. That's why combustion gases must be analyzed for *both* oxygen and combustibles to get a true indication of efficiency—and that is why Bailey coordinates both measurements on the same chart, to show when excess air may be reduced safely without danger of greater losses from unburned gases.

The Bailey Oxygen-Combustibles Analyzer is an approved combustion safeguard.

Ask your local Bailey engineer for suggestions on application. Equipment details in Product Specifications E65-1 and E12-5. CP107-1

Chemical and petroleum division

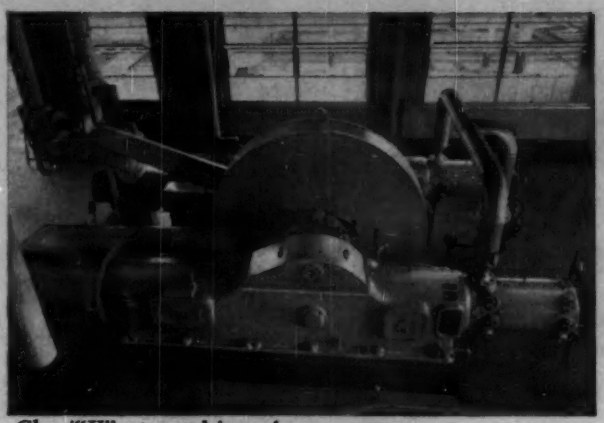
BAILEY METER COMPANY

1043 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

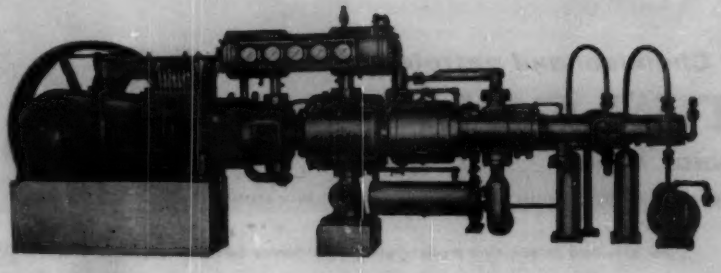
For more data on advertised products, use Readers' Service Cards, last page.

FOR EVERY PROCESSING REQUIREMENT THERE'S A CP COMPRESSOR MADE JUST FOR THE JOB



Class "H", steam-driven, four-corner, single-stage hydrocarbon gas booster.

Class "Y" butane compressor, coupled to an explosion-proof motor. In service in a large refinery.



Class "T", horizontal, straight-line, five-stage helium compressor. 6000 psig; 100 hp size.

Two

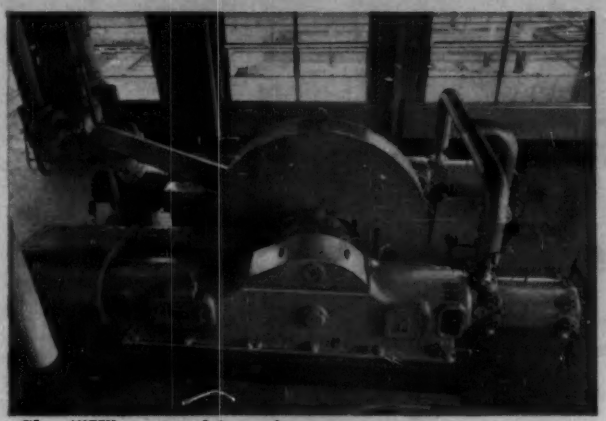
AIR AN

Two Class "FE" balanced-opposed compressors in process work. 3500 hp; five-stage.

Chicago Pneumatic 8 East 44th Street, New York 17, N. Y.

AIR AND GAS COMPRESSORS • VACUUM PUMPS • PNEUMATIC TOOLS • ELECTRIC TOOLS • DIESEL ENGINES • ROCK DRILLS • HYDRAULIC TOOLS

FOR EVERY PROCESSING REQUIREMENT THERE'S A CP COMPRESSOR MADE JUST FOR THE JOB



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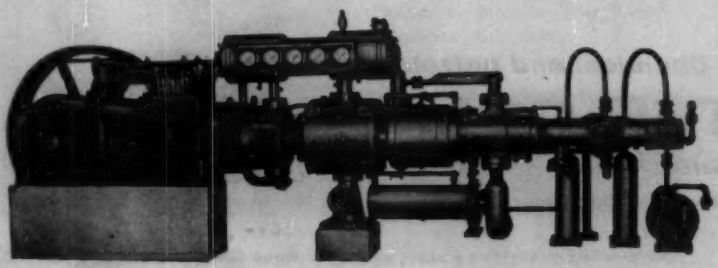
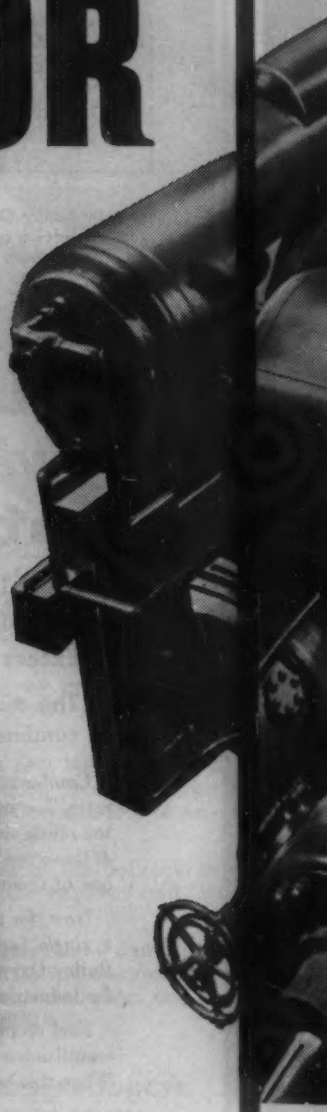


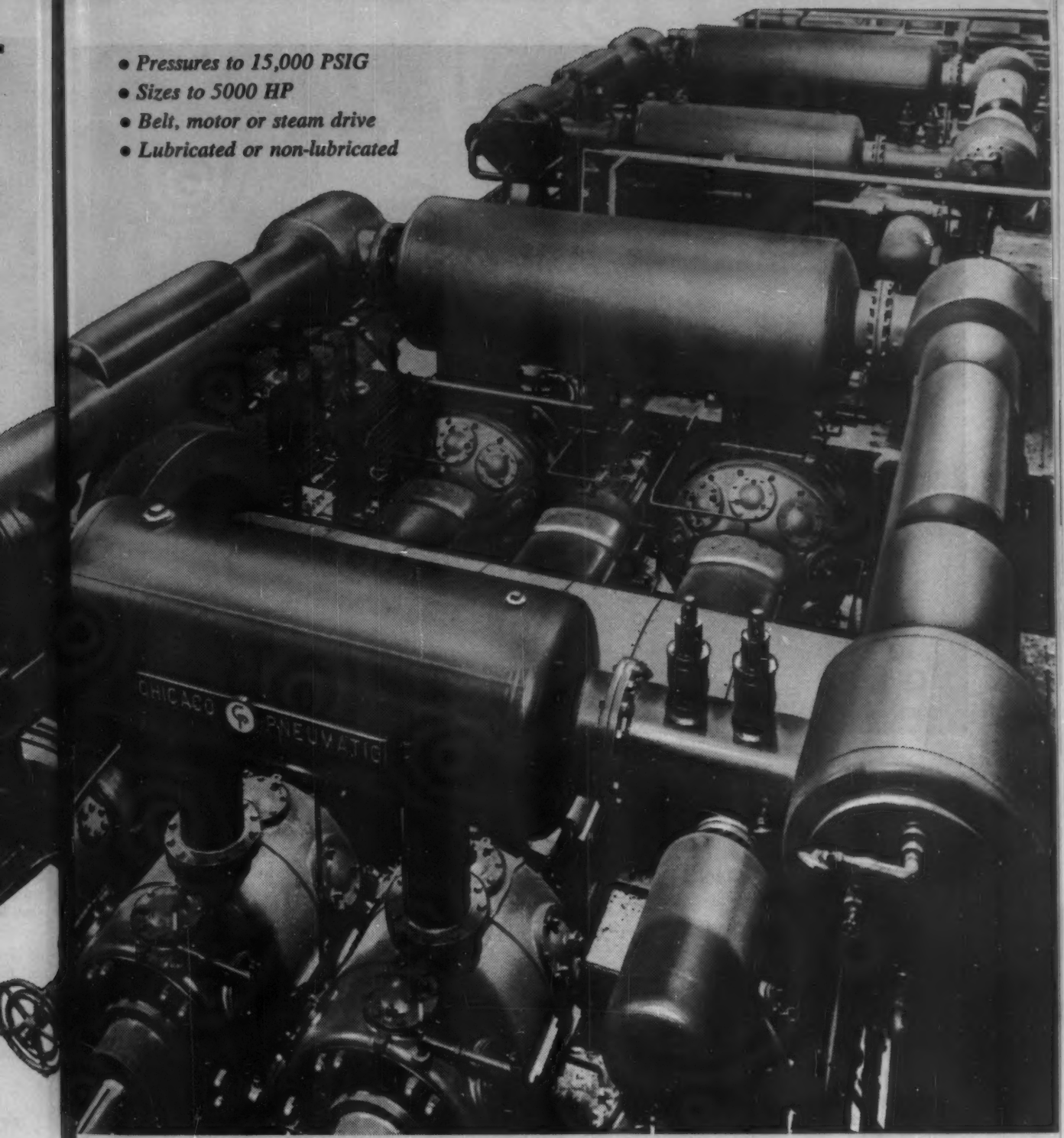
Class "T", horizontal, straight-line, five-stage helium compressor. 6000 psig; 100 hp size.



Two

AIR A

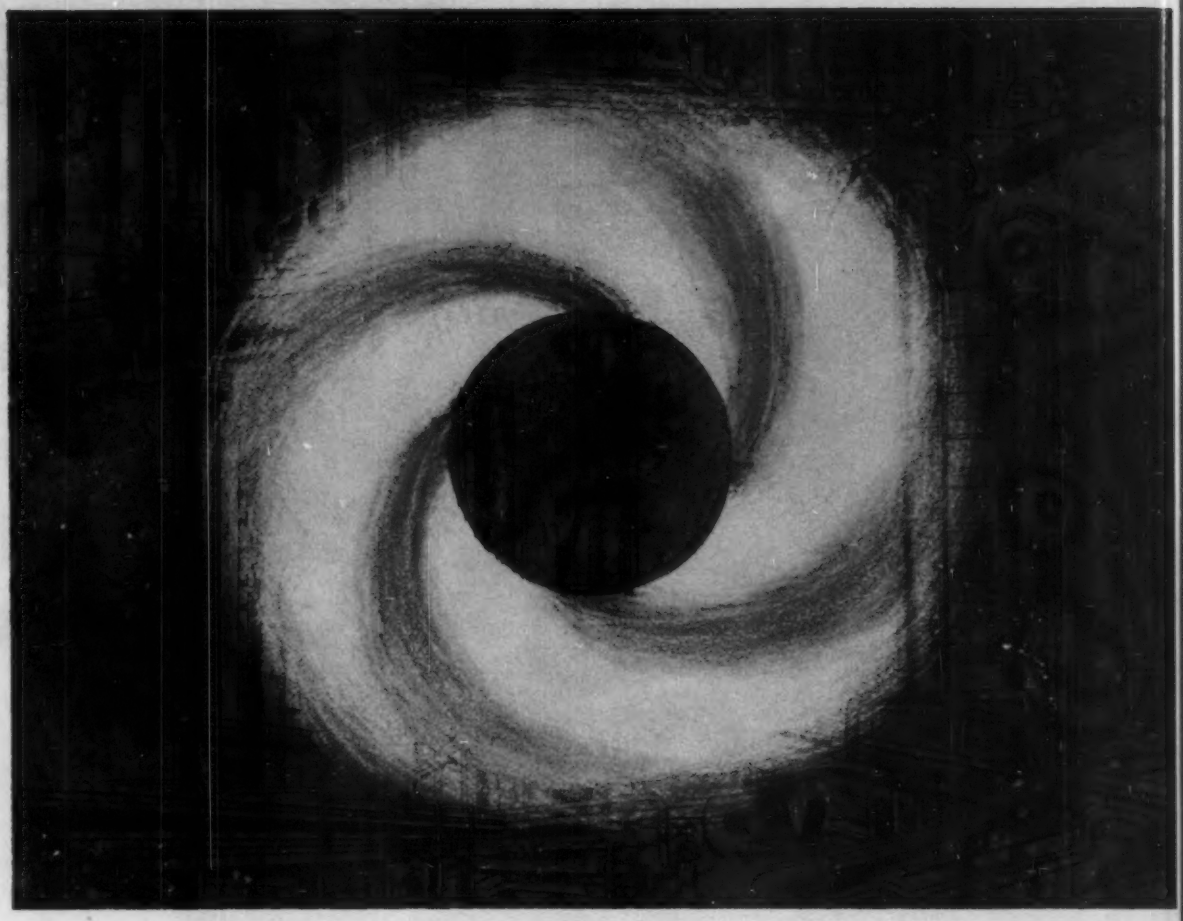
- *Pressures to 15,000 PSIG*
- *Sizes to 5000 HP*
- *Belt, motor or steam drive*
- *Lubricated or non-lubricated*



Two Class "FE" balanced-opposed compressors in process work. 3500 hp; five-stage.

Chicago Pneumatic 8 East 44th Street, New York 17, N. Y.

AIR AND GAS COMPRESSORS • VACUUM PUMPS • PNEUMATIC TOOLS • ELECTRIC TOOLS • DIESEL ENGINES • ROCK DRILLS • HYDRAULIC TOOLS



BROWN & ROOT

HAS DESIGNED AND INSTALLED MORE GAS TURBINE HORSEPOWER THAN ANY OTHER ENGINEER-CONSTRUCTOR

Of the total installations in the world, one out of every three gas turbine compressor drives used in the petroleum industry has been designed by Brown & Root. Today, over 1,735,000 horsepower of the relatively new gas turbine drive is at work in various branches of the industry.

With its own forces, Brown & Root has installed 75 per cent of the units it has designed, and is familiar with — and has used components of — all U. S. and many foreign gas turbine manufacturers.

In the over-all field of gas compression and power generation, Brown & Root has designed and installed a total of 1,620,000 horsepower.

If you are planning a gas turbine installation — anywhere in the world — your inquiry will receive our prompt attention . . . with no obligation.

BROWN & ROOT, INC.

Engineers · Constructors

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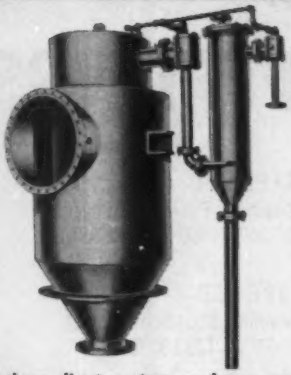
EDMONTON, ALBERTA
CABLE ADDRESS -- BROWNBILT

Nulli Secundus!

Graham 6 stage ejector capable of maintaining 4 microns absolute and handling 40,000 cu ft/min.

Single stage jet used on a 2 stage evaporator functioning as a thermo-compressor.



Graham direct contact condenser and 2 stage ejector—all of stainless 304 material.

Thank you, Brutus, old boy, for the right words! And, just as you say, the Graham Steam Jet Ejector *is* "second to none".

We have recently completed an extensive development program in our Batavia, New York engineering laboratory which has resulted in *added improvements* to the already high performance of Graham Steam Jet Ejectors. Design refinements worked out in this investigation mean increased stability, dependability and economy.

We now offer you the *finest performance available* from one to seven stages—a few inches of vacuum down to one micron of absolute pressure—evacuating small or large loads. Yes, Graham Ejectors are truly "second to none".

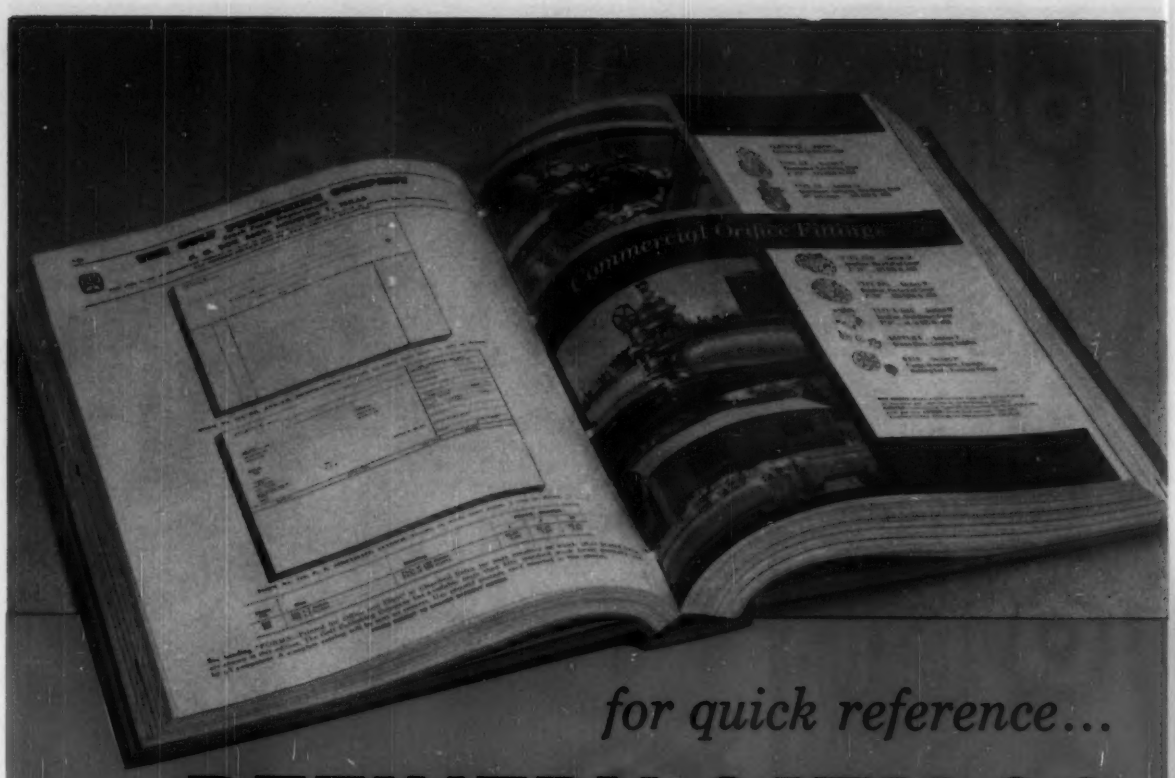
More information is contained in our Bulletin No. 70A. Send us your inquiries.

GRAHAM MANUFACTURING CO., INC.

Heliflow Corporation

170 GREAT NECK ROAD, GREAT NECK, N. Y.

Offices in principal cities and Canada



for quick reference...

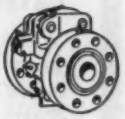
the REFINERY CATALOG

is the place to look for

COMMERCIAL ORIFICE FITTINGS

TYPE CN
Chambered, Non-Rising Stem
2"-20"... 125-2500 lb. ASA

TYPE CS
Chambered, Swinging, Non-Rising Stem
24" and larger... 125-600 lb. ASA



TYPE DPL
Deadline, Pin-Locked Cover
2"-24"... 600-2500 lb. ASA

TYPE DSB
Deadline, Stud-Bolted Cover
2"-24"... 125-600 lb. ASA

TYPE D-600
Deadline, Stud-Bolted Cover
2"-6"... up to 600 lb. ASA

COMMERCIAL IRON WORKS

2424 Porter Street, Los Angeles 21, California

Layne

SHORT COUPLED SERVICE PUMPS for any job

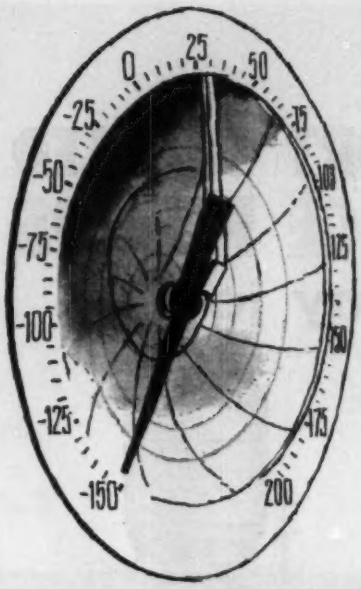
Capacities — 50 to 100,000 GPM
Heads — Up to 2,500 Ft.
Settings — As Specified
Discharge - Surface or underground

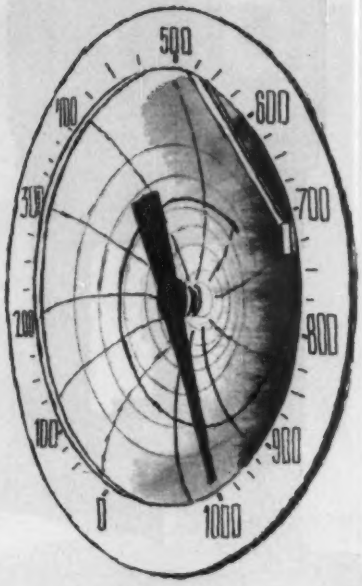
Top performance, high efficiency and less maintenance are factors which influence the selection of a short coupled pump. Layne Vertical Service Pumps fulfill these requirements and offer the advantages of lower installation and operation costs, low submergence requirements, simple alignment, no priming and less floor space demands. For any short coupled pumping job . . . specify Layne.

Write For Free Bulletins:
LAYNE TURBINE TYPE SERVICE PUMPS—NO. 300
LAYNE PROPELLER AND MIXED FLOW PUMPS—NO. 350

World's Largest Layne Water Developers

LAYNE & BOWLER, INC., MEMPHIS
General Offices and Factory, Memphis 8, Tenn.
LAYNE ASSOCIATE COMPANIES THROUGHOUT THE WORLD
SALES REPRESENTATIVES IN MAJOR CITIES

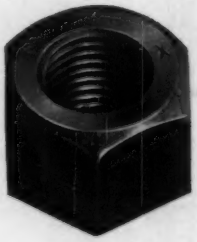




Whatever the temperature

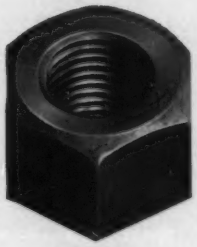
there's a Bethlehem Nut to do the job

Each meets ASTM Specification A-194.
Each comes in the full size range.



GRADE 2
moderately high temperatures and pressures

GRADE 2H
higher temperatures and pressures



GRADE 4
severe temperatures and pressures

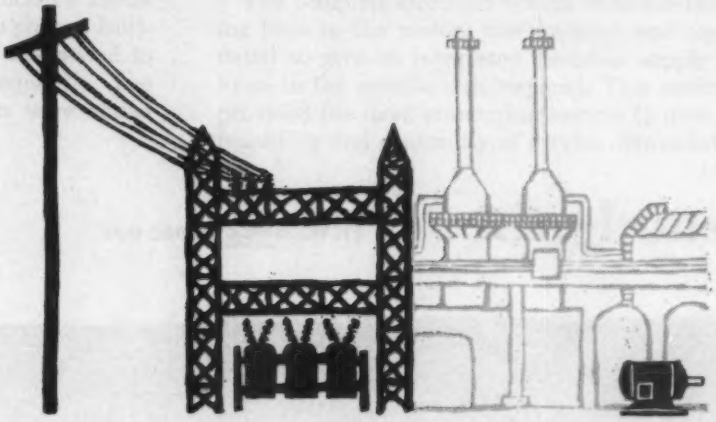
GRADE 4L
low temperatures

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
Export Distributor: Bethlehem Steel Export Corporation

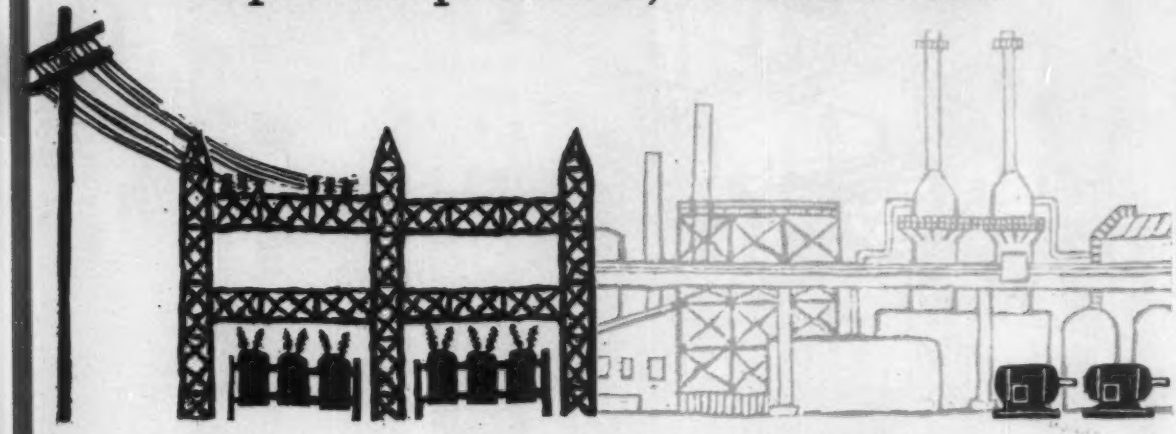
BETHLEHEM STEEL

BETHLEHEM STEEL

plan now to
POWER-UP FOR PROFIT ELECTRICALLY



Sinclair Refining did: increased production, improved products, reduced costs



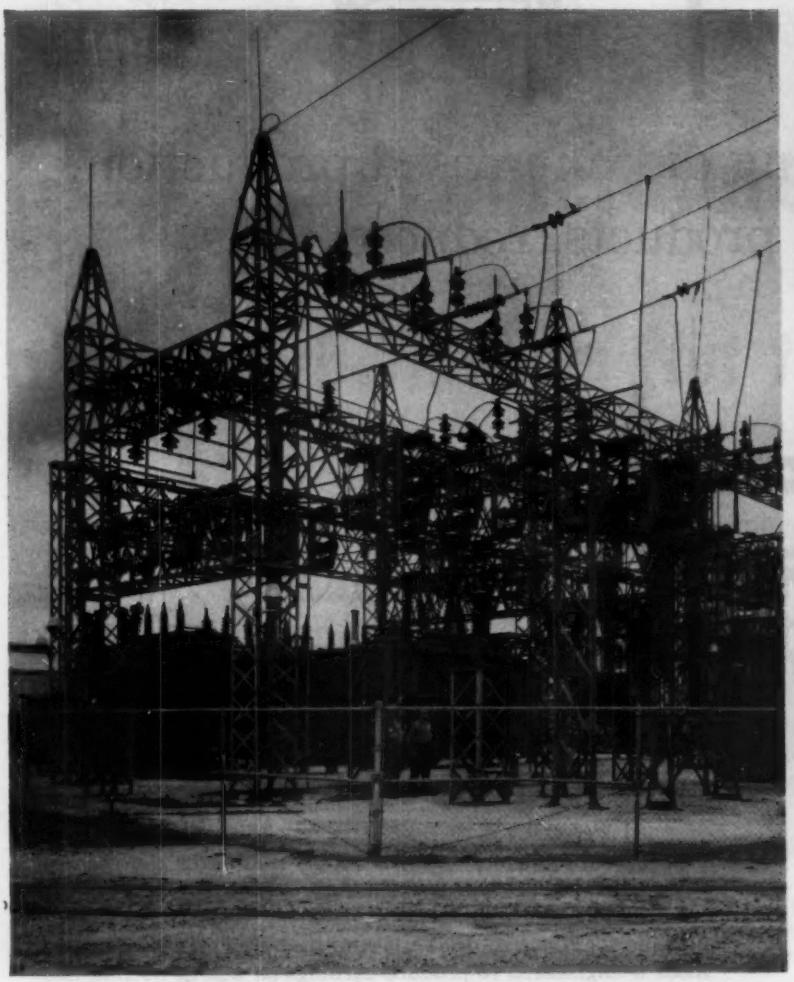
When Sinclair Refining modernized and expanded their Houston refinery, production increased and product quality improved. All this was accomplished through a carefully planned Power-Up program. The reliability of present-day electrical equipment and power supply minimized the amount of stand-by equipment needed.

You will need more capacity to meet the 40% increase in demand for goods by 1965. Be sure that your electrical equipment is engineered to produce earnings as well as output. See how Westinghouse helped Sinclair Refining to Power-Up.

YOU CAN BE SURE...IF IT'S **Westinghouse**

For more data on advertised products, use Readers' Service Cards, last page.

here's how Sinclair Refining



Main substation with two incoming 66-kv power lines is equipped with Westinghouse switchgear and transformers. Continuity of service is assured through the use of this dual feed to the refinery.

Relaying panels for protection of two incoming 66-kv lines, showing pilot wire and associated relays. These high-speed relays provide superior circuit protection by minimizing equipment damage and provide service continuity.

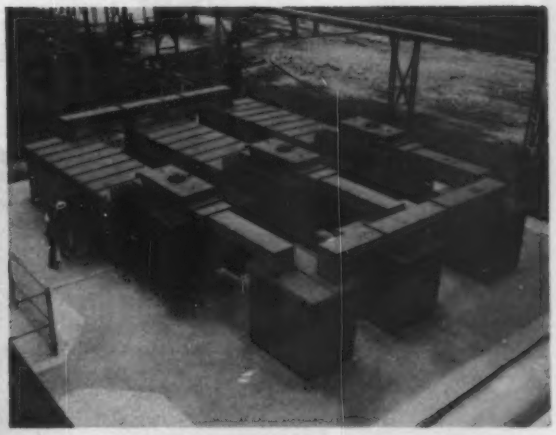
POWERED-UP with Westinghouse

Expansion and modernization at Sinclair's Houston refinery were carried out in two phases. Initially, a fluid catalytic cracking unit was added to expand the plant's capacity. Subsequently, two HDS (Hydrodesulphurization) units were added to improve the product quality.

The complete electrical system from the incoming lines to the motors was designed and coordinated to give an integrated electrical supply tailored to the specific requirements. This approach provided the most economical system to meet the reliability and continuity of service demanded.

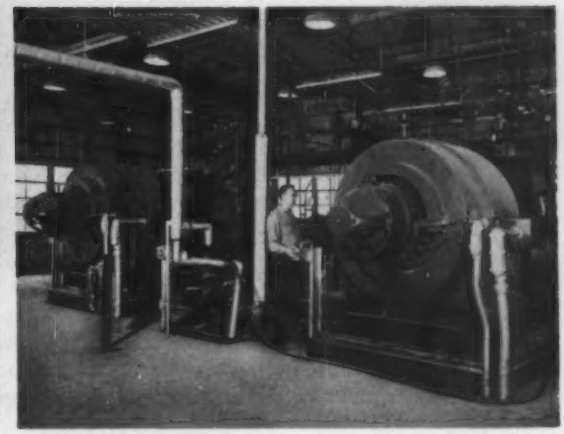
J-96131

YOU CAN BE SURE...IF IT'S **Westinghouse**



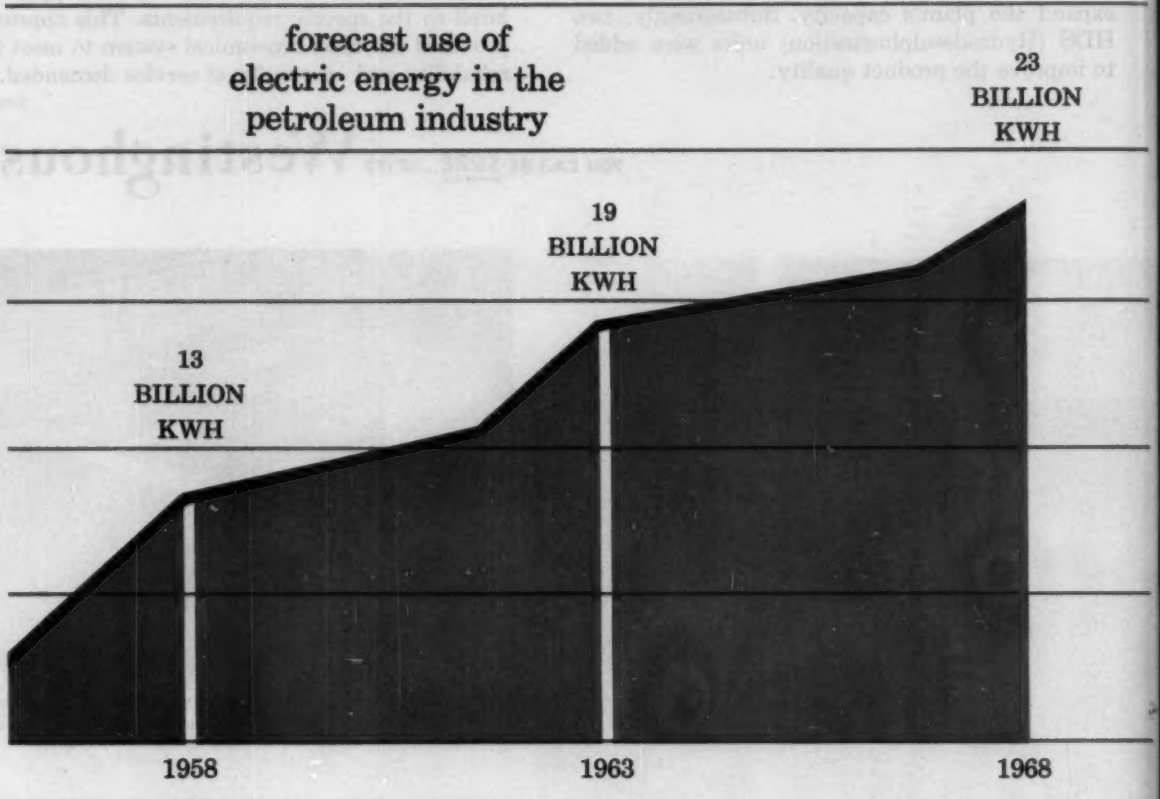
Unit substation with three 5000-kva transformers. Availability of alternate transformers and breakers provides the ultimate in reliability.

The refinery is served by three power transformers through three outdoor high-voltage switchgear assemblies interconnected by tie bus. Protective relaying system permits fast change-over, insures service even with power interruptions.



Large Westinghouse synchronous motors with Thermalastic® insulation which assures trouble-free operation and longer life. They are driving cooling water circulation pumps.

here's why you should plan now to
POWER-UP FOR PROFIT ELECTRICALLY



To stay competitive, you will be investing in a tremendous increase in electric power equipment. Be sure it is engineered to produce profits.

Greater use of electrical energy and up-to-date electrical equipment can help you get a better return on your investment through improved operations. In your plant it may be higher capacity machinery, more efficient equipment, or specially engineered controls.

Whatever the need, maximum use of low-cost kilowatthours can help you earn satisfactory profits. Your plant will need more capacity to meet the forecast 40% increase in the demand for goods by 1965.

Be sure—like Sinclair Refining—that your electrical equipment is engineered to produce earnings as well as output. Call your Westinghouse representative or your electric utility power sales engineer. They can tell you the electrical steps you can take *now* to start a Power-Up program in your plant. J-96131

YOU CAN BE SURE... IF IT'S **Westinghouse**

WATCH "WESTINGHOUSE LUCILLE BALL-DESI ARNAZ SHOWS" CBS TV FRIDAYS

Complete SCOPE of WATER CONDITIONING SERVICE from...

ALLIS-CHALMERS

End algae problems

easy, low-cost way

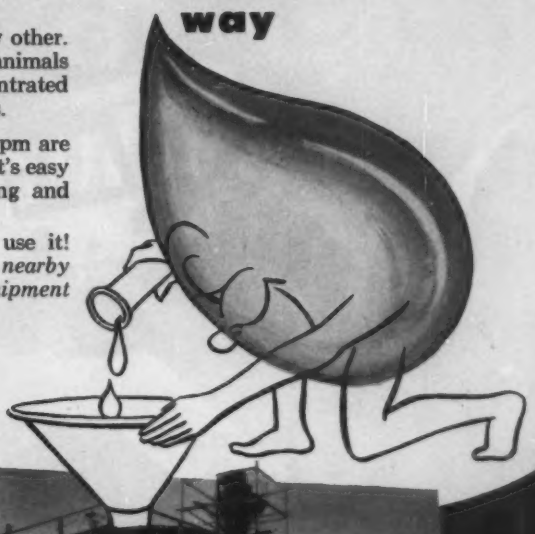
Eliminate problems of plugged pump strainers, coated heat-exchanger tubes and coated slots in cooling towers.

Control is safe . . . quick with Allis-Chalmers No. 120 Series Algaecide.

This algaecide is toxic to more algae than any other. On the other hand, it has low toxicity to fish or animals and is extremely safe to handle. Even in concentrated form it is only a mild irritant to skin and hands.

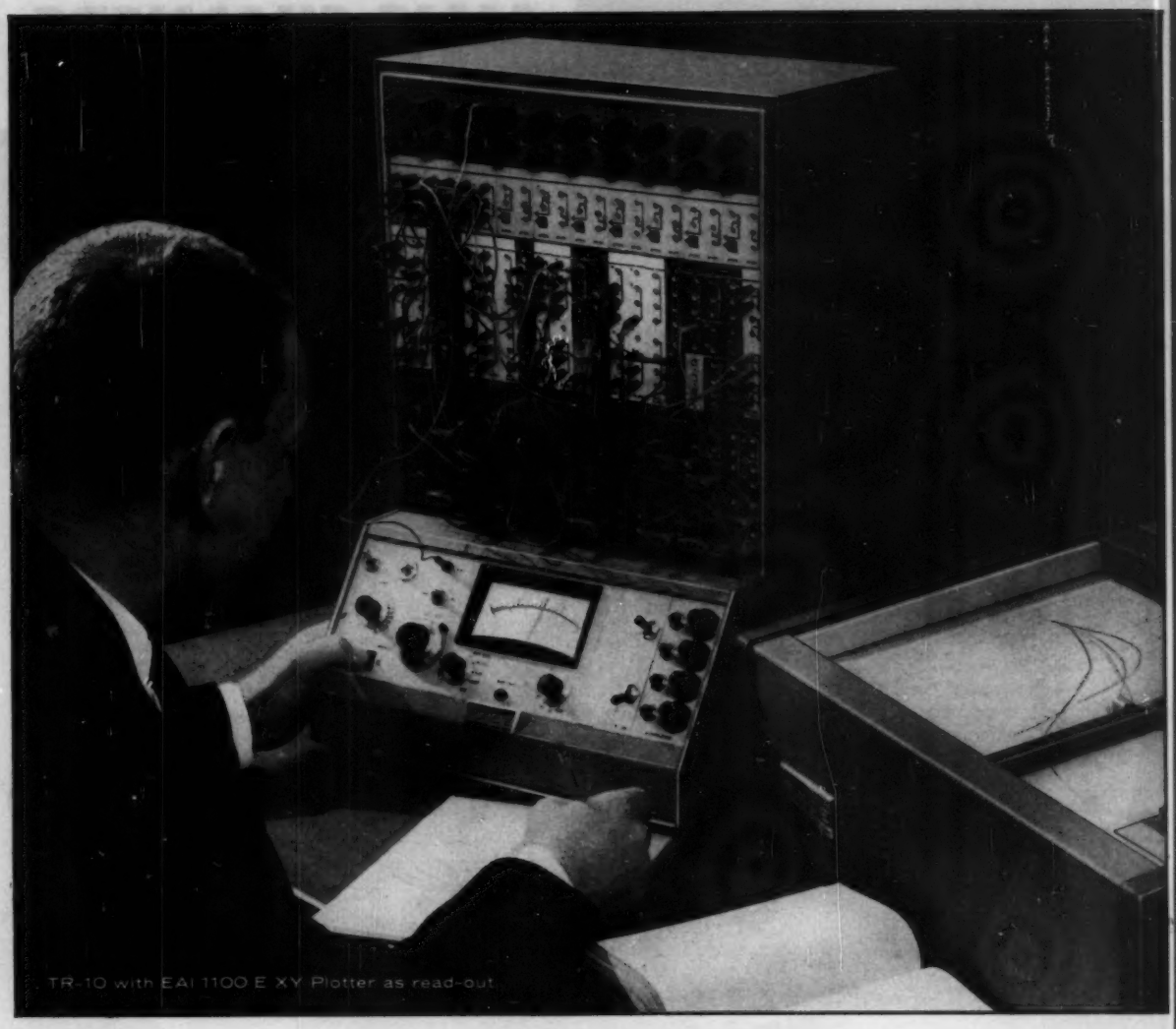
A little goes a long way! Only 2 to 5 ppm are required for effective dosage of most organisms. It's easy to feed into the system . . . and is non-oxidizing and corrosion inhibiting.

No water conditioning specialist needed to use it! Buy it and try it. *Purchase directly from your nearby A-C office or write Allis-Chalmers, Power Equipment Division, Milwaukee 1, Wisconsin.*



A-C ALLIS-CHALMERS

A 5972 C & P



TR-10 with EAI 1100 E XY Plotter as read-out

THE *FIRST* ALL TRANSISTORIZED ANALOG COMPUTER

—basic model less than $4000

PACE® TR-10 Eliminates Drudgery—Gives New Insight Into Engineering Problems

This compact unit, 15" x 16" by 24" high, is powered by 115 volts AC and can provide day-in day-out instant solution of your most vexing engineering problems. Even if you have never seen a computer before, you can learn to operate the TR-10 as easily as you learned to use a slide rule.

Simply turn a dial to feed in design parameters, and the computer provides an instant by instant, dynamic picture of the effect of each change. You can study the inter-related effects of heat, pressure, flow, vibration, torque or any variable, and visually compare one with the other. Engineering data comes alive – insight into how new designs will work is obtained easier, faster.

Because of its minimum size and low price, the TR-10 can become your own personal analog computer. You gain first-hand experience with the power of analog techniques, and convert more of your time to *creative engineering*. New ideas that were too costly to try before are now practical. You can design virtually to perfection and have a permanent, visual record of performance before building pilot models or prototypes. As a result, "cut and try" expense is reduced.

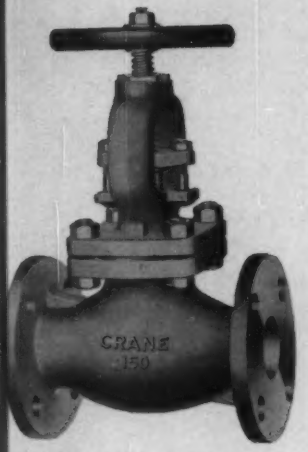
The same quality workmanship and design that has made Electronic Associates the world's leading producer of precision general purpose analog computers will be found in this new unit. Accuracy to ±.1 per cent. Modular construction allows you to select varying quantities of the following computing functions: summation, integration, multiplication or division, function generation, parameter adjustment, logical comparison.

For complete engineering data, write for Bulletin TR-10-L.

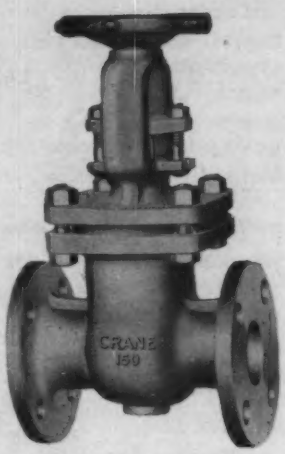
EAI ELECTRONIC ASSOCIATES, INC.
Long Branch, New Jersey

valves that beat your corrosion problems

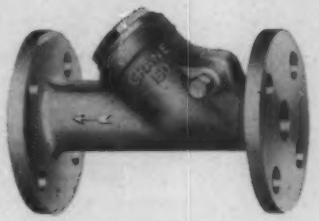
Crane 18-8 SMo and "Craneloy 20"



Globe and Angle Valves



Gate Valves



Swing Check Valves

CRANE STAINLESS STEEL VALVES

CRANE® VALVES & FITTINGS

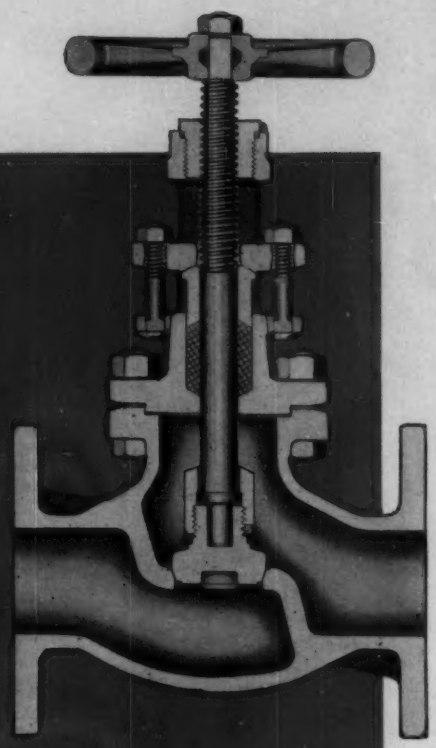
PIPE • PLUMBING • HEATING • AIR CONDITIONING

Since 1855 — Crane Co., General Offices: Chicago 5, Ill. — Branches and Wholesalers Serving All Areas

983—45M—8-59 PRINTED IN U.S.A.

CRANE

18-8 SMo and "CRANELOY 20" GLOBE and ANGLE VALVES *with Swivel Disc*



Performance-proved for sensitive flow control and positive sealing of highly corrosive fluids, vapors and gases

These corrosion-resistant valves were designed and perfected by Crane to combat the principal causes of valve damage: erosion, cutting and scoring. The stout heart of these valves is the

IMPROVED SWIVEL DISC-STEM DESIGN

The disc is a modified plug type, combining the easier seating of a narrow ball-to-flat seat and better resistance to erosion and scoring provided by a wide, plug-type disc.

In addition, Crane's exclusive "guided disc" design brings the stem thrust closer to the seating surface and assures positive closure. Minimum clearance between disc and stem eliminates vibration and chatter, but permits free swivel action at the disc-stem connection. As a result, the disc seats firmly with minimum torque and without galling and seizing.

All parts of these valves in contact with flow are Crane 18-8 SMo or "Craneloy 20," cast by Crane under closest supervision. See page 4 for composition of Crane 18-8 SMo and "Craneloy 20."

OTHER DESIGN FEATURES

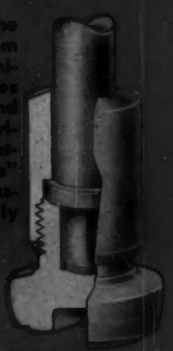
Body. Designed for smooth flow with minimum pressure drop and turbulence. Seats are integral.

Bonnet. Bolted OS&Y. Body-bonnet joints are retained gasket type. Stainless steel bolts, four or more, are used.

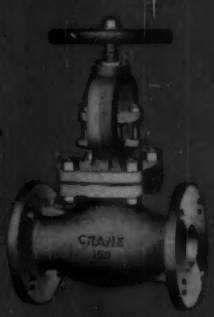
Packing gland. Two-piece, ball-type. Maintains uniform pressure on packing without danger of binding stem. Stainless steel carriage bolts are used.

Materials. Body, bonnet, stem, disc assembly, and packing gland —Crane 18-8 SMo or "Craneloy 20." Yoke bushing—cast manganese bronze. Teflon bonnet gasket. Teflon packing.

WORKING PRESSURES AND SIZES. Ten sizes, ½" to 6". 150 psi at 500 F; 230 psi at 100 F. Screwed and flanged ends. Flanged facings have serrated finish. All valves OS&Y.

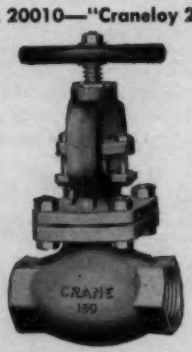


Close-up of Crane swivel disc-stem connection. Minimum clearances between disc and stem prevent vibration and chatter. Long "guide" on end of stem assures accurately aligned seating.



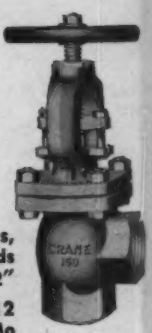
Globe valves, flanged ends ½" to 6"
No. 18811 18-8 SMo
No. 20011 "Craneloy 20"

Globe valves, screwed ends ½" to 2"
No. 18810—18-8 SMo
No. 20010—"Craneloy 20"

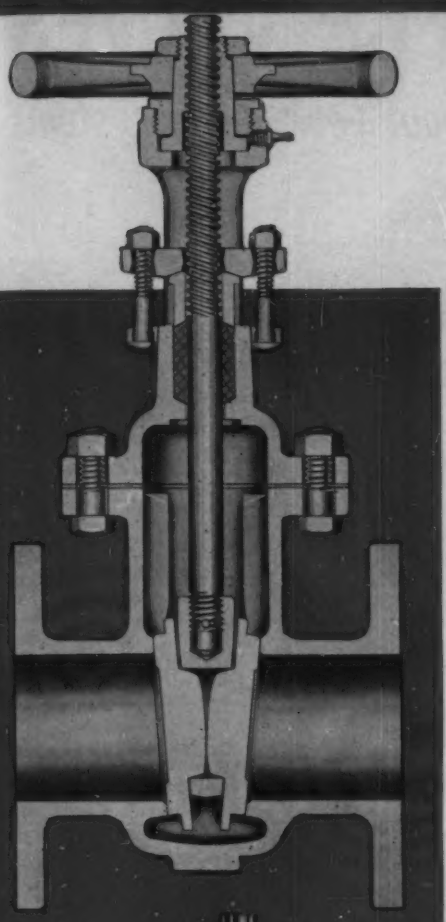


Angle Valves, flanged ends ½" to 6"
No. 18813 18-8 SMo
No. 20013 "Craneloy 20"

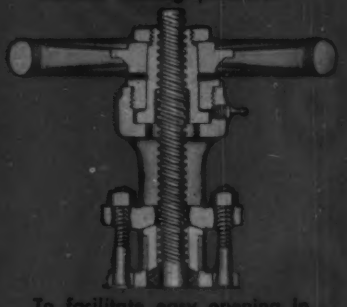
Angle valves, screwed ends ½" to 2"
No. 18812 18-8 SMo
No. 20012 "Craneloy 20"



CRANE



Crane split-wedge disc design. Identical disc halves assure uniform seating pressure.



To facilitate easy opening in valves 2½" and larger, Crane provides a grease fitting for stem lubrication.

18-8 SMo and "CRANELOY 20"

GATE VALVES

with Split-Wedge Disc

Designed for long life, tight seating, easy operation and low cost maintenance on toughest corrosive services

Corrosion . . . wear . . . galling . . . seizing—all costly enemies of valves in petroleum and petrochemical processing plants—meet their match in Crane 18-8 SMo and "Craneloy 20" gates.

Key to the success of these popular valves is the unique seating design perfected by Crane. The potential weaknesses of ordinary split-wedge disc valves used on corrosive services have been eliminated.

CRANE SPLIT-WEDGE DISC DESIGN

This simple construction features identical disc halves (an exclusive Crane development), which means that seating loads are transmitted equally to each half, assuring uniform pressure on seating faces. There is no danger of buckling a weaker disc member, as in conventional ball and socket disc construction. In opening, the first turn of the handwheel frees the discs—even if the valve is closed hot and opened cold.

Special guide flanges on the discs, *another Crane feature*, prevent disc drag across the seat during operation. This means longer seat life. The free-to-rotate discs prevent concentrated wear, galling and seizing.

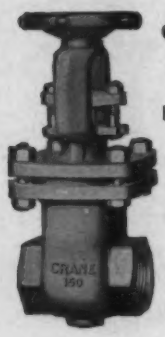
All valve components in contact with flow are Crane 18-8 SMo or "Craneloy 20." All castings are produced under rigid control in Crane's own foundry. Stuffing boxes are packed with tough, resilient, non-contaminating Teflon.

CRANE QUALITY IN EVERY DETAIL

1. Internal areas proportioned for smooth flow, minimum turbulence.
2. Teflon stem packing.
3. Two-piece, ball-type packing gland. Assures uniform pressure on packing without binding stem.
4. Crane exclusive split-wedge disc assembly.
5. Teflon bonnet gasket.

Materials. Crane 18-8 SMo or "Craneloy 20" in body, bonnet, stem, disc, disc carrier and gland. Integral seats. Stainless steel bonnet and gland bolts. Cast manganese bronze yoke sleeve. Malleable iron handwheel. See page 4 for composition of Crane 18-8 SMo and "Craneloy 20."

WORKING PRESSURES AND SIZES. 13 sizes—½" to 12". 150 psi at 500 F; 230 psi at 100 F. Screwed and flanged ends. Flanged facings regularly have serrated finish. All valves OS&Y.



Gate valves—screwed ends ½" to 2"

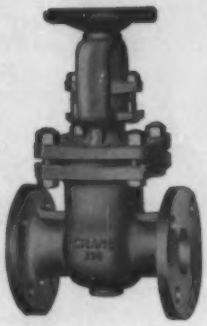
No. 18844—18-8 SMo

No. 20044—"Craneloy 20"

Gate valves—flanged ends ½" to 12"

No. 18845—18-8 SMo

No. 20045—"Craneloy 20"



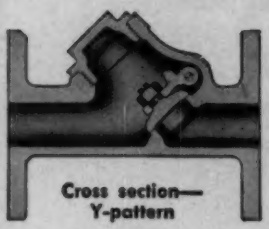
CRANE STAINLESS STEEL VALVES

CRANE

18-8 SMo and "CRANELOY 20"

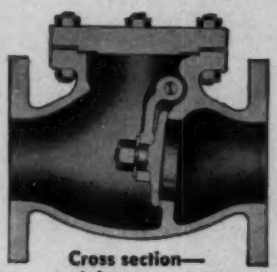
SWING-CHECK VALVES

to help maintain Crane quality throughout your piping systems



Cross section—
Y-pattern

Y-pattern valve features. Valve is equipped with an access opening in line with the seat; disc can be rotated with a screw driver to permit regrinding of seating surfaces without removing the valve from the line. Smooth interior contour assures easy flow.



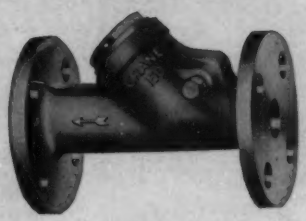
Cross section—
straightway pattern

Straightway valves. Integral seat, with seat face at minimum angle from vertical to permit smooth flow with low turbulence. Cap secures tightly with stainless steel bolts and nuts, yet permits easy dismantling for maintenance.

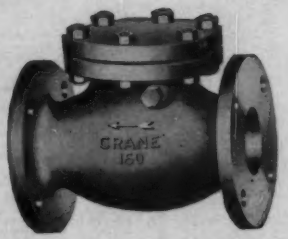
WORKING PRESSURES AND SIZES

Ten sizes: Y-pattern, ½" to 2"; straightway pattern, 2½" to 6". 150 psi at 500 F; 230 psi at 100 F. Y-pattern valves in screwed and flanged ends. Straightway valves in flanged ends only.

**Y-pattern—
screwed ends
½" to 2"**
No. 18826—18-8 SMo
**No. 20026
"Craneloy 20"**



**Y-pattern—
flanged ends
½" to 2"**
No. 18827—18-8 SMo
**No. 20027
"Craneloy 20"**



**Straightway pattern
2½" to 6"**
No. 18829—18-8 SMo
**No. 20029
"Craneloy 20"**

More Complete Data on Request

You can safely order Crane Stainless Steel Valves from data given here. But for your files, you should have this 12-page bulletin giving complete technical and specification data on these valves. It includes a helpful, dependable application guide covering many corrosive fluids. Ask for bulletin AD-2080—from the Crane man calling on you—or write to address below.

Ask for Bulletin AD-2080

New Pipe Joint Compound Prevents Galling GET TRIAL SUPPLY FREE

You can eliminate seizing and galling in alloy pipe joints—screwed and flanged—with this compound. Crane Improved Formula 425-A "Anti-Seize" Thread Compound keeps joints lubricated indefinitely, even under high loading and long exposure to temperatures as high as 1050 F. Use it on pipe threads, gaskets, flange faces and bolts. It helps you make a tighter metal-to-metal joint, and helps you open the joint without damage to piping materials. Conforms to Spec. MIL-A-907. Supplied in 1- and 4-pound cans. Ask your Crane Representative for free trial tube and literature.

CRANE® VALVES & FITTINGS

PIPE • PLUMBING • HEATING • AIR CONDITIONING

Since 1855 — Crane Co., General Offices: Chicago 5, Ill. — Branches and Wholesalers Serving All Areas

Septem

GRINNELL CONSTANT SUPPORTS...

2 BASIC DESIGNS... 11 DIFFERENT METHODS OF ATTACHMENT

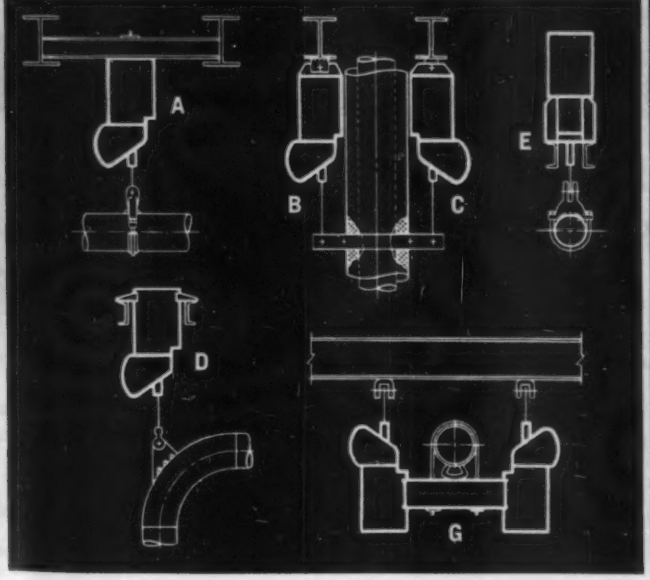
Grinnell Constant Supports are available in a range of sizes to provide capacities for loads from 27 lbs. to 57,500 lbs., with travels up to 16 inches.

Both vertical and horizontal hangers are designed to operate in extremely limited space. In the selection of types, there is a choice of 11 methods of attachment to structures—either above, between, or below supporting steel.

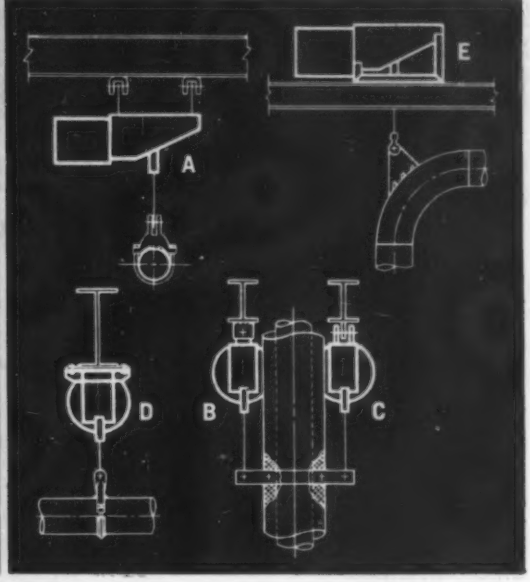
Grinnell Constant Supports provide mathematically perfect load support throughout all positions of travel . . . also a full 70 percentage points of adjustability is built into them. No less than 10% of this adjustability is allowed either side of calibration for plus or minus change in load. Field readjustments are easily made by turning a single load adjustment bolt.

Call on Grinnell's Pipe Suspension Department for help with your pipe suspension problems. Grinnell Company, Providence 1, Rhode Island.

FOR VERTICAL ATTACHMENT



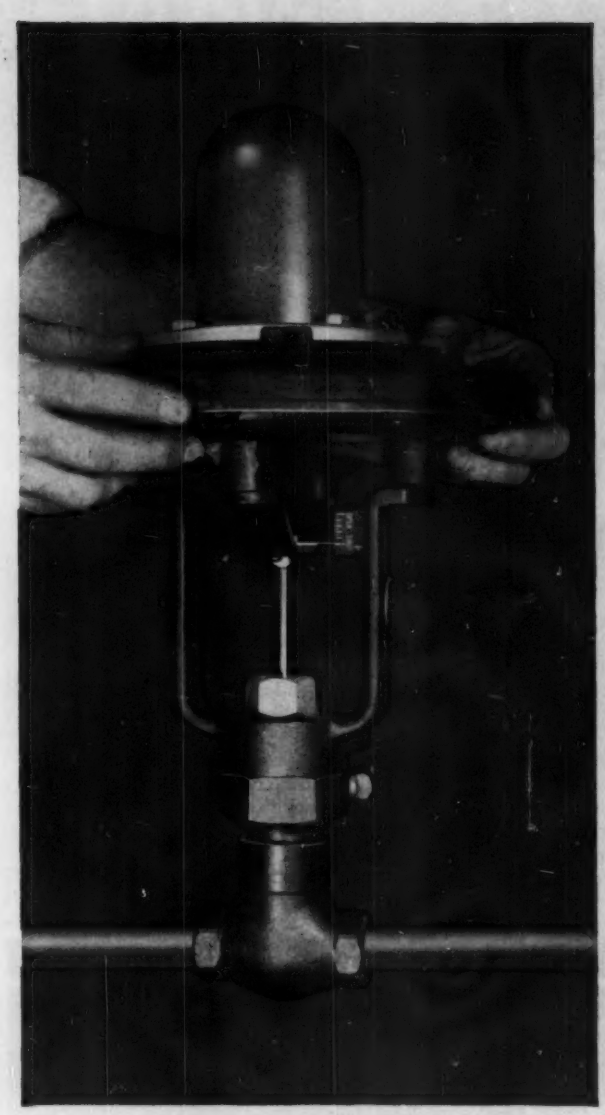
FOR HORIZONTAL ATTACHMENT

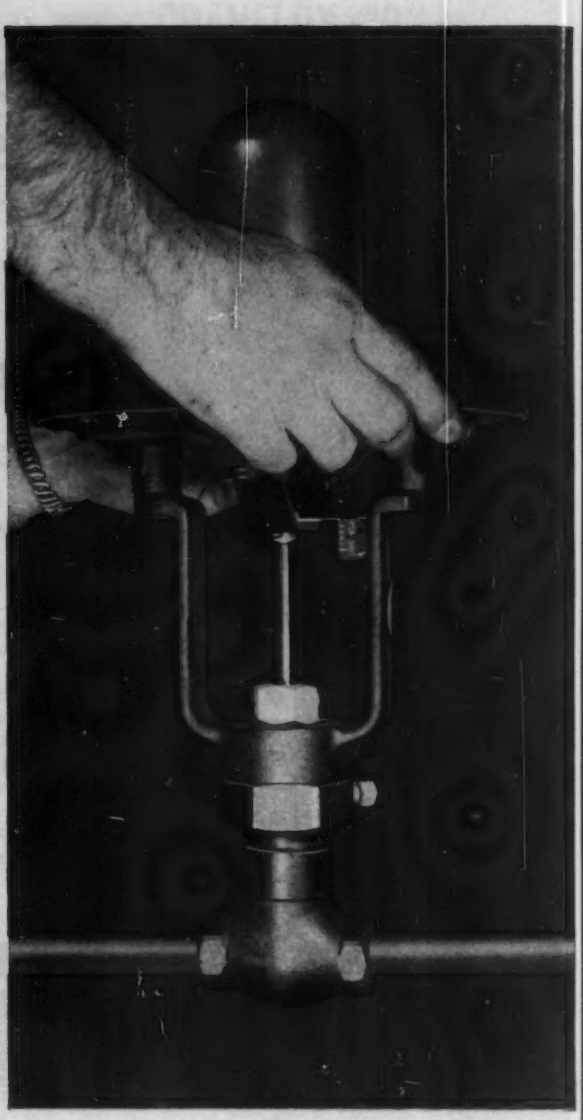


GRINNELL

AMERICA'S No. 1 SUPPLIER OF PIPE HANGERS AND SUPPORTS

For more data on advertised products, use Readers' Service Cards, last page.





LOOK HOW EASY IT IS TO REVERSE THE ACTION OF A FOXBORO CONTROL VALVE!

air-to-open . . . air-to-close — one valve for the job of two

Unbolt the motor casing and rotate it 90°; rebolt and shift air connections — that's all you do to reverse the operation of a Foxboro control valve. Takes just a few minutes — without touching valve body or process piping — without employing special tools or skills.

Foxboro reversible motors are especially suited for needle valves, Saunders-type valves, and other control valves having non-reversible bodies. They're also used with Foxboro Stabilflo* Valves — the original valves with equal percentage flow characteristics and wide 50 to 1 rangeability.

Foxboro control valves with their quick-reversible valve motor, are an exclusive Foxboro development. They're perfect for pilot plant operations and other processes frequently "juggled." Types and materials to meet any process requirement.

Write for detailed bulletins today. **The Foxboro Company, 649 Neponset Ave., Foxboro, Mass.**

*Reg. U.S. Pat. Off.

FOXBORO

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of heat loss with
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PRECISION-MOLDED
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a Calcium Silicate
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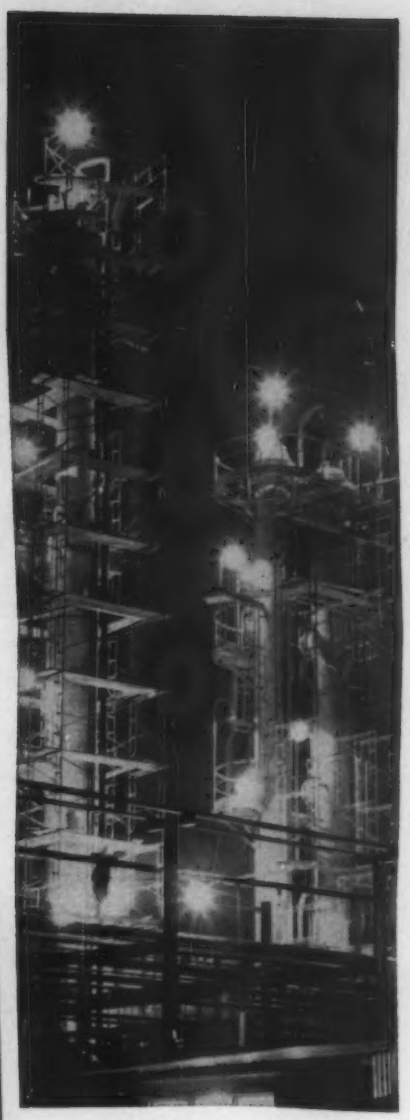

INSULATION GUIDE

Temperature	Recommended Pabco Insulation		
to 550°	85% Magnesia pipe covering	block	cement
to 1200°	Caltemp pipe covering	block	cement
to 1500°	Prasco 15 C pipe covering	block	cement
to 1900°	Prasco 19 C	block	

PABCO

INDUSTRIAL INSULATIONS DIVISION
Fibreboard Paper Products Corporation
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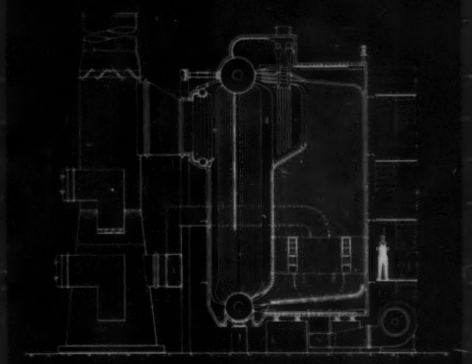
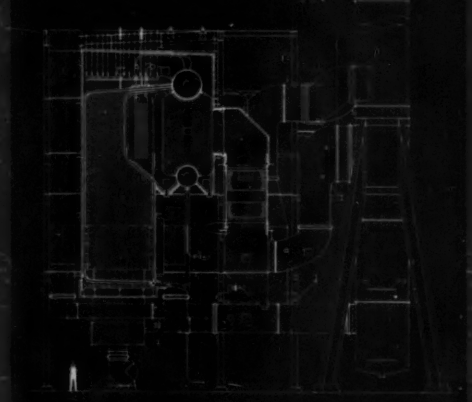
For more data on advertised products, use Readers' Service Cards, last page.



C-E VU-50B CO Boiler (above)—offers same construction and design as C-E's standard VU types. Features tangent waterwalls—welded skin casing—tangential firing—minimum number of baffles—economic advantages of bottom supports. Proven in hundreds of installations, this VU design gives high standards of performance with economy of operation, reliability, and minimal maintenance. This design is especially suitable where the quantities of CO gas burned are relatively small.

The design on this page represents a plan section diagram showing arrangement of C-E Tangential Burners for firing a completely water-cooled furnace.

C-E VU-40 CO Boiler (below)—this is a top-supported CO boiler installed at a Gulf Coast refinery. The plant cycle for this unit combines a catalyst regenerator, two gas turbine-driven compressors, two CO boilers, and separate turbine exhaust gas feedwater heaters located between the boilers.



Now tangentially fired C-E boilers for any quantity of catalyst regenerator gas for any quantity of steam required

which assure

- complete combustion
- maximum control
- low power consumption
- minimum exposed refractory

C-E now has an expanded line of CO boilers that offer refineries the opportunity to profitably use the energy potential of even small quantities of catalyst regenerator gas. This makes available to refiners a wide range of C-E CO boiler sizes, all offering *big boiler* features. *All* incorporate the advantages of Combustion's service-proved VU-40, a top-supported design, or the smaller, more economical bottom-supported VU-50B boilers – and all are tangentially fired.

Tangential firing assures efficient combustion of CO gas with a minimal use of supplemental fuel . . . not only at high loads, *but also at low load*. Tangential burners assure the turbulence and complete mixing essential to efficient burning when the CO fuel mixture is injected into the furnace from minimum to maximum load.

Combustion's widespread experience has encompassed all types of steam generating equipment, including many installations firing lean fuels. If you have need of a boiler to burn catalyst regenerator gas, it's C-E for CO.

For detailed catalog on CO Boilers by C-E, mail this coupon.

Name_____ Title_____

Company_____

Address_____

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C-178

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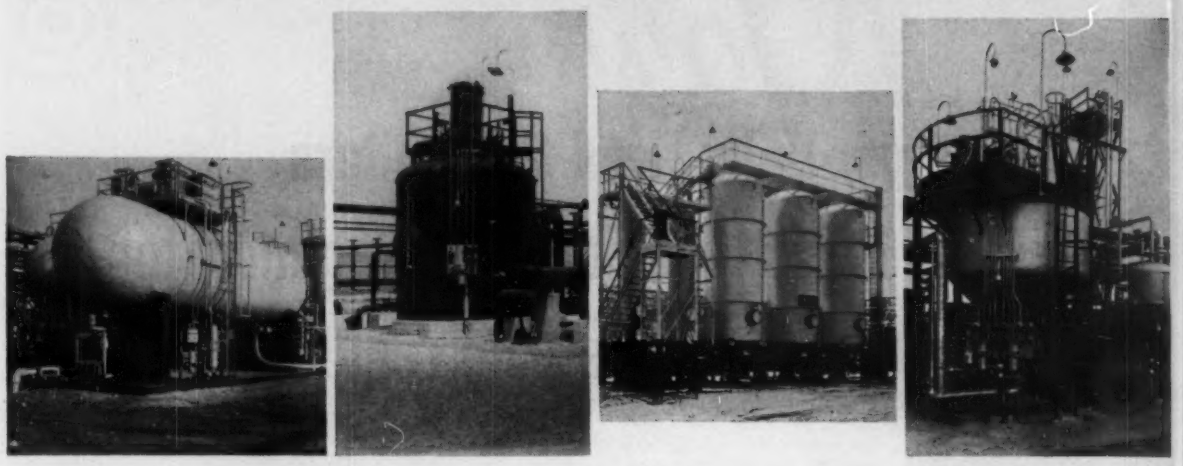
ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

PRODUCT IMPROVEMENT WITH

PETRECO



Four case histories show how PETRECO processing equipment prevents pollution*

Air and stream pollution are critical problems in refineries all over the country. The following installations show how PETRECO* Precipitation Equipment is helping to solve these pollution nuisances.

FUMES FROM OPEN TYPE ACID-LUBE AGITATORS were plaguing the residential area adjacent to a Gulf Coast refinery. PETRECO Electric Acid Lube Treating Equipment was installed. Being a closed unit, no toxic fumes escaped. The "solid" acid sludge of the former method was replaced by one that was fluid, easy to handle and simple to re-convert. Also, less acid was required to obtain a specification product and less oil was lost to sludge.

PHENOLIC WATERS FROM PHILADELPHIA AREA REFINERY were causing stream pollution problems. A PETRECO Electric Desalter was installed to purify the charging crudes. The phenolic waters were used to water-wash the salty crude. Result: the effluent from the desalter was phenol and oil free. The water pollution problem was solved.

CAUSTIC AND OIL FROM TREATMENT OF BURNING OIL were seriously contaminating the streams in a Great Lakes area. Over 8000 pounds of caustic- and oil-polluted water were being dumped every month. An ELECTROFINING* Precipitator was installed for the caustic treatment. Oil and caustic in the effluent were reduced to negligible level and the pollution problem was immediately corrected. In addition, product specifications were met at a savings of about 7600 pounds of caustic per month, because of the more intense utilization of the caustic with Petreco equipment.

CAUSTIC AND DOCTOR TREATMENT WASTES were polluting local streams and adding noxious vapors to the atmosphere near a Gulf Coast refinery. A Petreco Bender Catalytic Sweetening plant was installed. Since, in the Bender process, there is no product loss and no spent black-strap, there is no possible source of pollution. The PETRECO Processing Equipment stopped *two* kinds of pollution—air and water.

In refineries all over America, similar pollution problems are being solved daily with Petreco equipment. In the Los Angeles area, for example, one refinery is doing its part to combat the local "smog" problem with seven different Petreco installations—and, typically, producing better products at lower cost.

FOR FURTHER DETAILS on PETRECO Processing Equipment, write or call...

*PETRECO and ELECTROFINING are registered trademarks of Petrolite Corporation

AR 59-1

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Bingham

STUFFINGBOXLESS PUMPS

HANDLE LIGHT HYDROCARBONS* AT HIGH SUCTION PRESSURES

NO STUFFING BOX! NO PACKING!

Bingham Stuffingboxless Pumps are successfully handling liquids having high vapor pressure, requiring high suction pressure and, frequently, abnormally low pumping temperature (—300°).

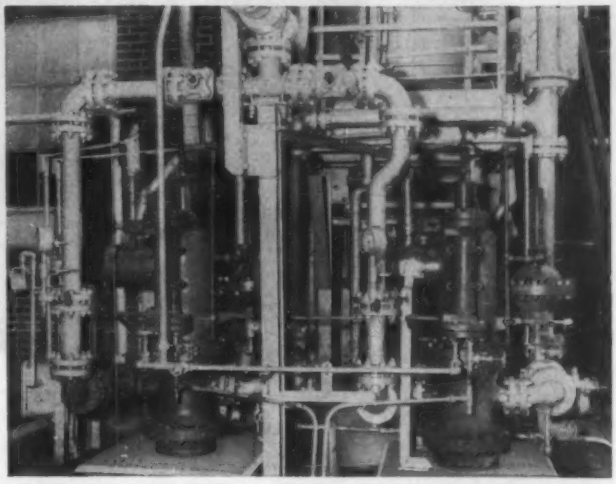
Standard models handle suction pressures up to 2,000 psi (higher pressures available). Pumping temperatures to 850° F. and higher also can be handled.

Bingham Stuffingboxless Pumps are in service today all over the world, with distinguished records in reliability, continuity of service, and low maintenance. Write to your nearest Bingham office for Bulletin 107 or for additional information.

*And other volatile liquids.

BINGHAM STUFFINGBOXLESS PUMPS OFFER:

- Lower overall installed cost
- Less operating attendance
- No misalignment of moving parts
- Smooth operation
- No auxiliary lubricating system
- No exposed moving parts
- Positive motor cooling
- All parts are accessible



Bingham Type KT Stuffingboxless Pumps handling **liquid propane** under high suction pressure at Esso Standard Oil Company refinery, Bayway, New Jersey.

PARTIAL LIST OF MAJOR OIL COMPANIES USING BINGHAM STUFFINGBOXLESS PUMPS

British American Oil Co., Ltd.
Carbide & Carbon Chemical Co.
Canadian Industries
Cities Service Company
Creole Pipe Line Company
Dow Chemical Co.
E. I. duPont de Nemours & Co.
ESSO Standard Oil Co.
Great Lakes Pipe Line Co.
Gulf Oil Corp.
Imperial Oil Company Ltd.
Mitsui Petrochemical Industries, Ltd.
National Petrochemical Co.
Polymer Corporation
Phillips Petroleum Co.
Stanolind Oil & Gas Co.
Sinclair Oil Company
Sohio Petroleum Co.
Standard Oil Company of Indiana
Tennessee Gas & Transmission Co.
Tide Water Associated Oil Co.
Texas Company
Warren Petroleum Co.

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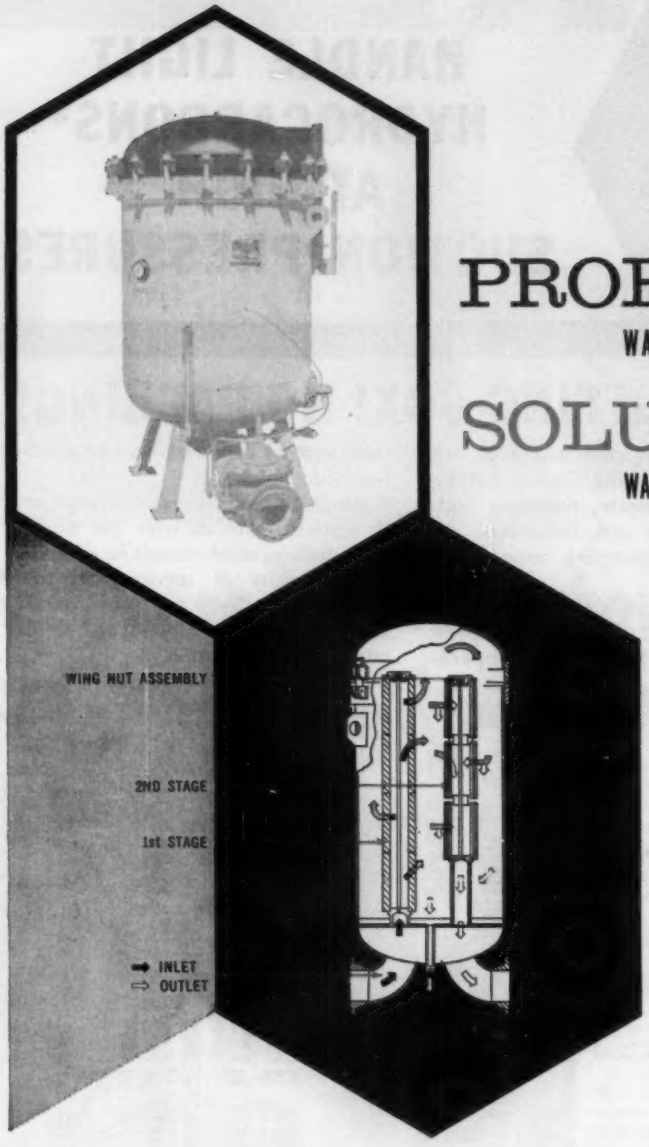
VANCOUVER, B. C., CAN.



PROBLEM:

WATER AND DIRT IN PETROLEUM PRODUCTS

SOLUTION:

WARNER LEWIS TWO STAGE SEPARATOR/FILTERS

For Process, Pipeline and Marketing Facilities

HOW IT WORKS

1st Stage — Coalescing-Filtering

Hydrocarbon and water enter inlet and pass through the coalescer cartridges where solids such as dirt, rust and scale are removed and mechanical emulsions are broken. Finely dispersed water droplets gather together into large water droplets and fall by gravity into the water-collecting sump.

2nd Stage — Separating

Clean hydrocarbon and any entrained water droplets flow to the separator cartridges. This chemically-treated media completely blocks the passage of water and clean hydrocarbon passes through the cartridges to the outlet.

Two stage design provides positive protection against contaminated products not possible in single stage designs.

Replacement cartridges feature high dirt holding capacity and low cost replacement.

Write Process Section, Warner Lewis Company, for details.

WARNER LEWIS COMPANY
BOX 3096 • TULSA, OKLAHOMA

DIVISION OF FRAM CORPORATION

Here, boiling nitric acid is used to evaluate the corrosion resistance of Jessop stainless steel plate.

"How Jessop Tests Stainless Steel in Boiling Nitric Acid"

L. W. Cooper, Chief Metallurgist

"From experience, our customers know this is a fact: Specify Jessop for specialty steels . . . and then relax! Of the many reasons *why* this is true, here's one . . .

"In evaluating corrosion resistance, one of the procedures we use is the ASTM boiling nitric acid test. Standard and simple? Yes. But expert *evaluation* is of great importance to the customer. That's why, at Jessop, a top metallurgist closely supervises each of the five 48-hour test periods.

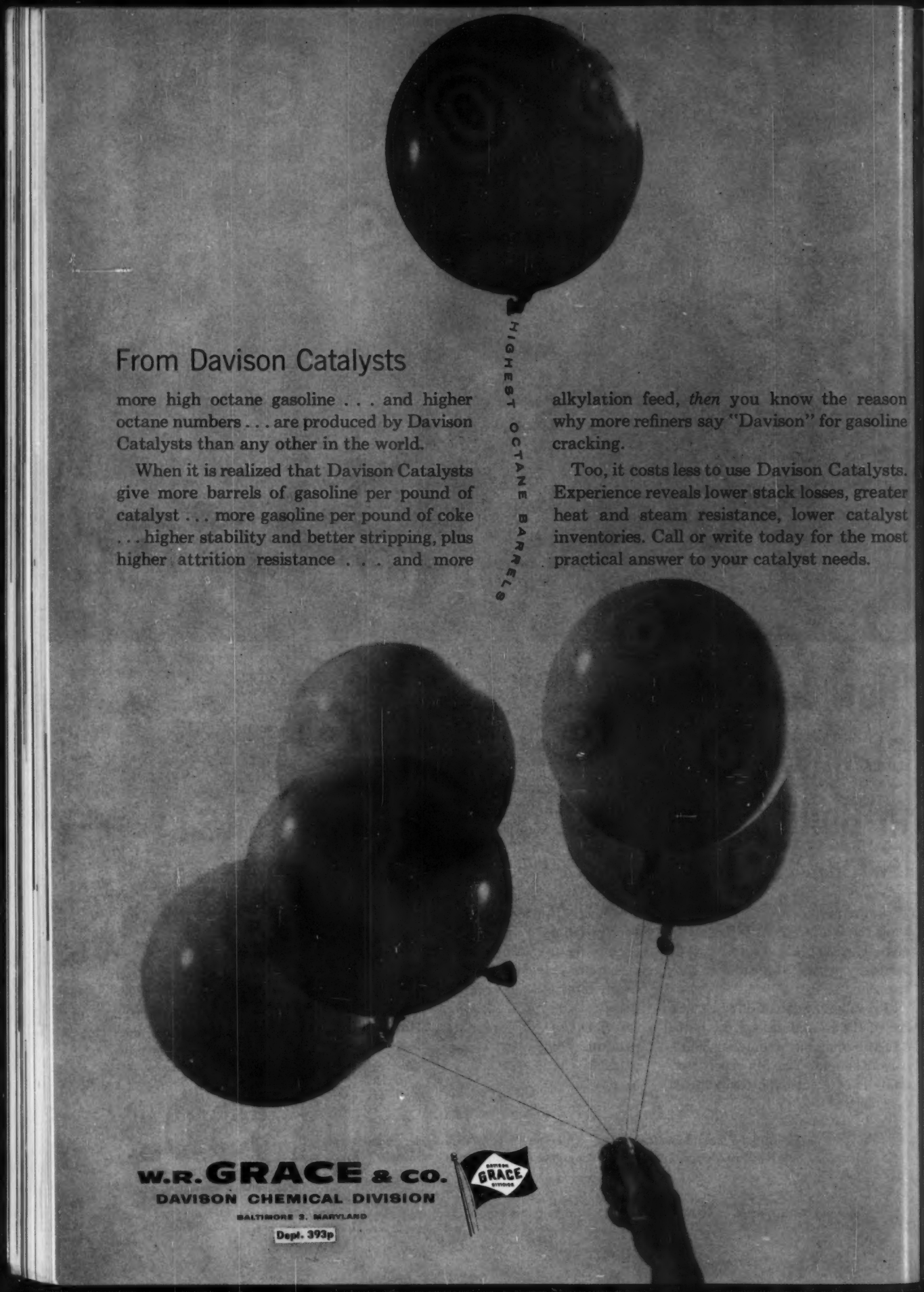
"*Overly cautious?* Because we're overly cautious in *every* phase of steel production and quality control, Jessop has earned the reputation for producing specialty steels tailor-made to the most exacting specs—*Specify Jessop . . . and then relax!*"

Checking the grain size of tool steel, this Jessop metallurgist uses a microscope with a camera attachment. VHA 6787

Green River Steel Corporation
Jessop Steel of Canada, Ltd.
Jessop Steel International Corporation
Steel Warehousing Corporation, Chicago

JESSOP
STEEL COMPANY
Washington, Pennsylvania

Stainless, alloy, tool, cast-to-shape, clad, and forging steels, ground flat stock and other specialty steels



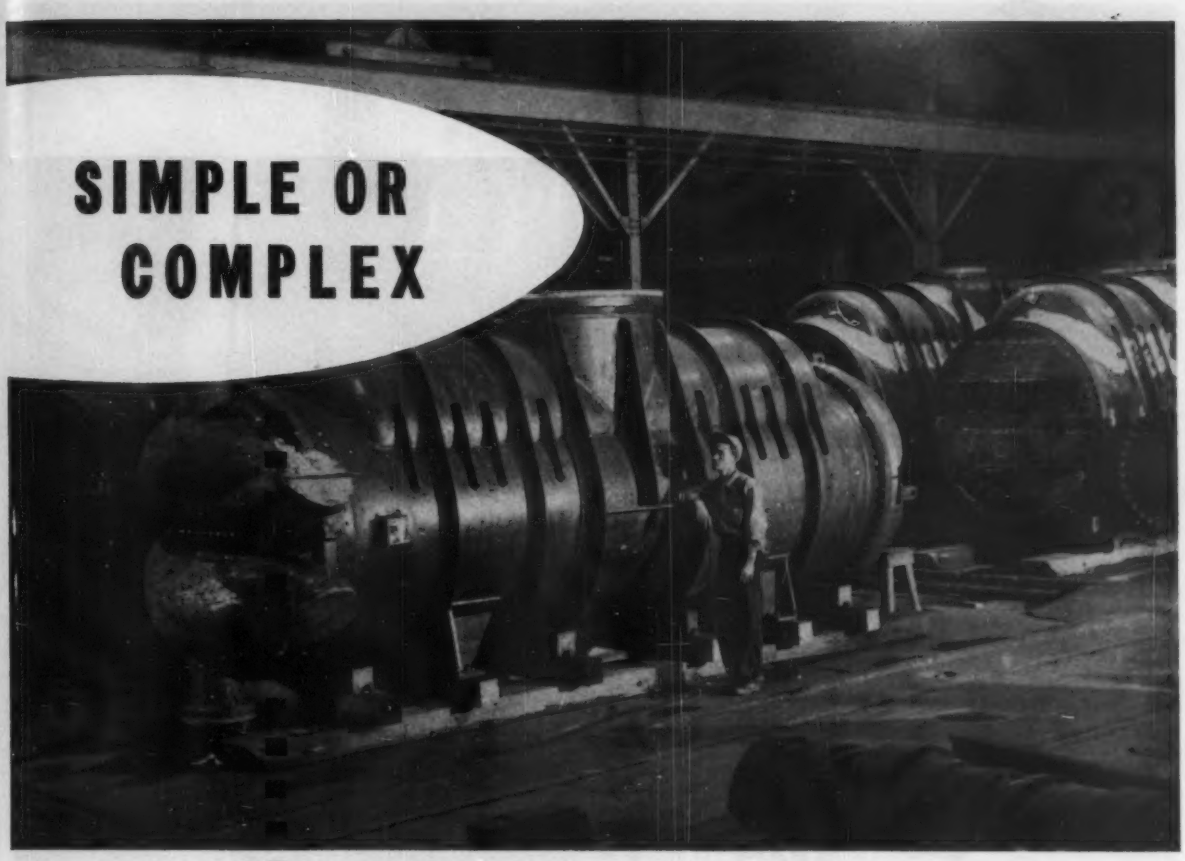
From Davison Catalysts

more high octane gasoline . . . and higher octane numbers . . . are produced by Davison Catalysts than any other in the world.

When it is realized that Davison Catalysts give more barrels of gasoline per pound of catalyst . . . more gasoline per pound of coke . . . higher stability and better stripping, plus higher attrition resistance . . . and more alkylation feed, *then* you know the reason why more refiners say "Davison" for gasoline cracking.

Too, it costs less to use Davison Catalysts. Experience reveals lower stack losses, greater heat and steam resistance, lower catalyst inventories. Call or write today for the most practical answer to your catalyst needs.

W.R. GRACE & CO.
DAVISON CHEMICAL DIVISION
BALTIMORE 3, MARYLAND
Dept. 393p



SIMPLE OR COMPLEX

EFCO does it right

No job is too complicated for Efco's heat-transfer specialists. One reason that Efco does it *right* is its many years of experience in designing and fabricating heat-exchangers for the wide range of temperatures and pressures represented by ethylene plants and platinum catalyst reforming units. We are recognized specialists in handling all grades of carbon, alloy, and stainless steels, nickel, aluminum, and special low-temperature materials.

EFCO'S FOUR POINT PROGRAM PROVIDES:

service-proved engineering design
guaranteed job-ratings
complete fabricating facilities
technical service before, during and after installation

ASK OUR GULF COAST CUSTOMERS — THEY KNOW US WELL

Write for General Catalog

EFCO HEAT TRANSFER EQUIPMENT
Engineers and Fabricators, Inc.
P. O. BOX 7395 **HOUSTON 8, TEXAS**

EFCO

For more data on advertised products, use Readers' Service Cards, last page.

US RUBBER

SOLVENT PACKINGS

"We tested one packing after another... but only 'U.S.' could stand up,"

Says CHEMICAL PLANT SUPERINTENDENT

When a leading mid-western chemical company put their new plant into operation in 1955, they faced a problem with pump packings: To find a packing resistant to a combination of solvents, caustic and high temperature—with a minimum of shaft wear.

"We tested one packing after another on our caustic pumps," says the plant superintendent, "and found that U. S. Solvent Packing outlasted any other packing tested *by as much as 10 to 1.*"

Result: No more morale-breaking "clean-up" sessions, production is increased, personal injuries due to leaks have been reduced 75%, and there's no need for rescheduling due to breakdowns.

A "U. S." technician, of course, worked with engineers of the chemical company to develop the right packing for this particular requirement. That's part of the "U. S." service, when needed.

• • •

When you think of rubber, think of your "U. S." Distributor. He's your best on-the-spot source of technical aid, quick delivery and quality industrial rubber products.

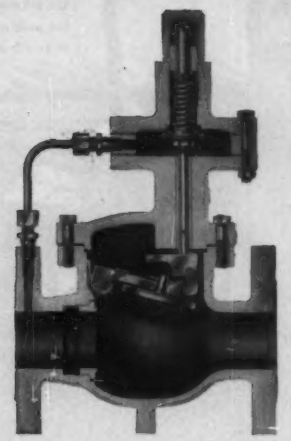
US RUBBER

Mechanical Goods Division

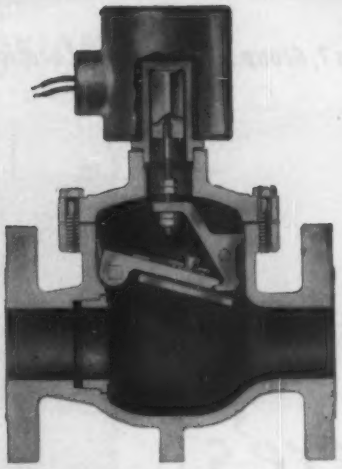
United States Rubber

WORLD'S LARGEST MANUFACTURER OF INDUSTRIAL RUBBER PRODUCTS

Rockefeller Center, New York 20, N.Y. In Canada: Dominion Rubber Company, Ltd.

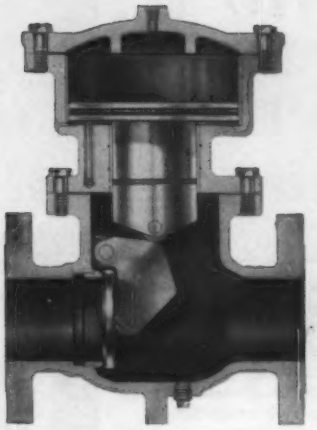


Model 1500H shown, is a high pressure shut-off valve which closes automatically and instantly when predetermined high pressure is reached. With addition of a fusible metal plug, valve can be furnished to shut off on overpressure and/or over-temperature. With control pressure above diaphragm, valve can be made into a low pressure shut-off valve. Combination high and low pressure shut-off also available.



Model 1700 shown, is a Solenoid operated valve normally energized to maintain valve in open position. On interruption of electric current valve closes instantly. Model 1800 Solenoid shut-off valve available to shut off gas instantly by applying electric current either automatically or through a "panic" button.

Instant action, sure and safe with Coppus Sentry® Valves



Model 3000 shown, is a piston operated valve, which opens instantly when pressure above the piston is released. Restoring the pressure above the piston closes the valve. The operating pressure above the piston can be obtained from the line or from an independent source of gas or liquid and can be automatically released or applied by instrument air or gas operated pilots or by use of a small three-way Solenoid valve.

Sentry Valves assure better protection of personnel and property. Instant, split second action with full flow, available in two basic types. Sentry Latch type valves for instant automatic closing; Sentry Piston type valves for automatic opening and closing.

The Latch type requires manual reset — the piston type can be opened and closed automatically.

Sentry Valves can be actuated by high or low pressures, by excessive temperatures, by excessive flow or electrically by use of a Solenoid.

Standard sizes — all Full-Flow — in steel or meehanite 1½" to 8".

To get more detailed information on this outstanding line of Coppus Sentry Valves send the coupon.

ANOTHER
COPPUS
"BLUE RIBBON" PRODUCT

COPPUS ENGINEERING CORPORATION
420 Park Avenue, Worcester 2, Mass.

Please send Bulletin 500.

Name.....

Company.....

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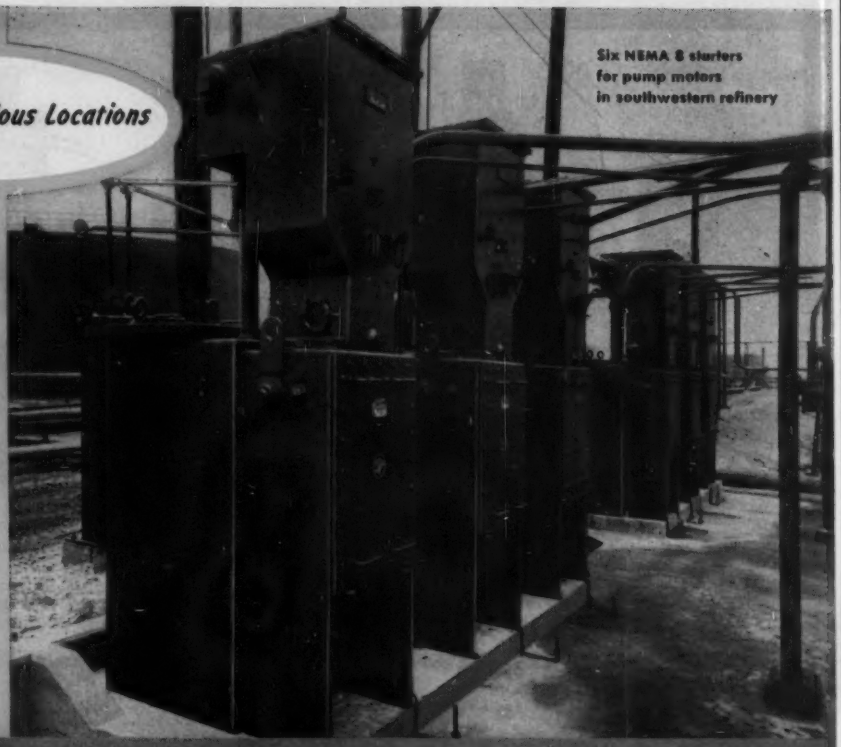
For more data on advertised products, use Readers' Service Cards, last page.

for Class 1, Group D, Hazardous Locations

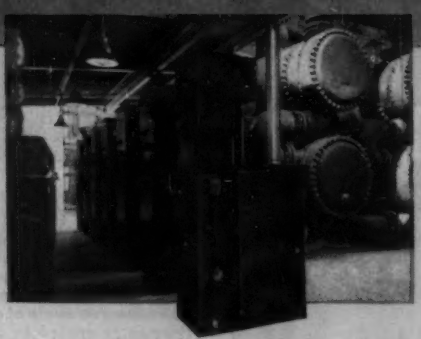


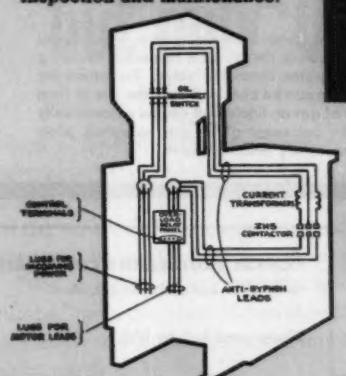
Six NEMA 8 starters for pump motors in southwestern refinery

here's how to

SAVE SPACE and INSTALLATION TIME with EC&M HIGH VOLTAGE STARTERS

SPACE SAVERS! Each of the seven starters in the eastern refinery installation *(at the right)* requires a space of only 2 ft. x 4 ft.—permitting close grouping with maximum accessibility for inspection and maintenance.





YOU SAVE INSTALLATION TIME because every EC&M starter is shipped with all internal wiring complete. *(See diagram at left)* All leads are of anti-syphon construction.

Write for Bulletin 8131 AM

These EC&M 2200-4800 volt Starters are designed for use where hazardous mixtures of air and inflammable gases or vapors are ever-present. NEMA 3R (raintight) enclosure permits mounting indoors, outdoors, or in semi-enclosed location. Load-break oil disconnect switch is self-contained and completely wired into the starter.

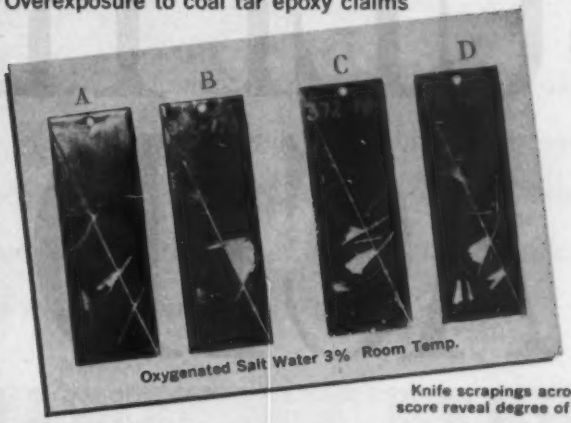
Available in two ratings for any power capacity. (*1*) 50,000 KVA (certified) interrupting capacity of EC&M Type ZHS Contactor. (*2*) In VALIMITOR® (volt-ampere-limitor) style... the bus may be of unlimited capacity.

THE ELECTRIC CONTROLLER & MFG. CO.
A DIVISION OF THE SQUARE D COMPANY
CLEVELAND 28 • OHIO

7936

SUFFERING FROM COALTAREPOXICATION?*

*Overexposure to coal tar epoxy claims



Knife scrapings across diagonal score reveal degree of undercutting.

Caustic Soda 5% Room Temp.

Sulfuric Acid 10% Room Temp.

Sulfuric Acid 30% Room Temp.

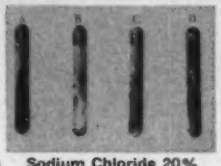
Sodium Hypochlorite 5% Room Temp.

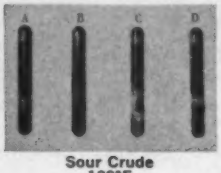
Aviation Gas 100/130 Octane Room Temp.

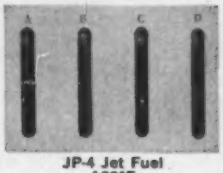
Salt Spray (scored panels) Room Temp.

Distilled Water 140°F

Distilled Water Boiling


Sodium Chloride 20% Boiling


Sour Crude 120°F


JP-4 Jet Fuel 120°F

Aromatic petroleum hydrocarbon solvent—120°F

Try these tests to end the confusion

116

So many conflicting claims have been made about virtually every coal tar epoxy coating on the market that prospective users are finding it difficult to fish out the facts from a sea of superlatives.

Perhaps you can find *your* answer by duplicating any or all of these laboratory tests comparing the four leading coal tar epoxies.

THE TESTS: The rods and panels illustrated here were carefully coated to the four manufacturers' specifications and then subjected for three months to the corrosive agents indicated above. The wide range of tests included varying concentrations of chemicals, ambient and elevated temperatures, weathering and all usual types of exposure.

THE RESULTS: Some results were predictable, such as the failure of all four coatings to withstand aromatic petroleum hydrocarbon solvent. But striking differences occurred in such tests as oxygenated salt water, when only Coating A (Amercoat No. 78) resisted undercutting. Products B, C and D were all blistered and undercut to varying degrees. In none of the remaining tests was Amercoat No. 78 excelled, and in most cases it showed marked superiority.

CONFIRMATION: The properties attributed to No. 78 in these tests have been substantiated repeatedly in actual field use. Applicators like it because it (1) gives dependable, all-around protection, (2) sprays more easily than competitive products, (3) builds thick films without difficulty because of its higher solids content, and (4) dries thoroughly but at a moderate rate, avoiding the extremes of prolonged tackiness and fast-dried brittleness.

Because of the unusual importance of these tests to prospective users of coal tar epoxy coatings, we have prepared illustrated copies of the complete report. Write for yours today!

(Amercoat No. 78 was formerly designated No. 1686)

Amercoat® CORPORATION

Dept. VI
4809 Firestone Boulevard
South Gate, California

921 Pitner Ave. Evanston, Ill. 360 Carnegie Ave. Kenilworth, N.J 2404 Dennis St. Jacksonville, Fla. 6530 Supply Row Houston, Texas

For more data on advertised products, use Readers' Service Cards, last page.

SULPHURIC ACID

to 1/10th of 1%

Tailor-made for YOUR Process

as delivered

Do you use 100.3%? Or 96.1%?

You name it and we deliver it ready for your processing line.

What's more... deliveries are prompt and dependable. Consolidated's big fleet of tank cars, trucks and barges is handled by an exceptionally skilled traffic department. Movements are traced day by day ...and we load and start shipments so they reach you on time.

And don't forget... if spent sulphuric acid is one of your problems, our regeneration facilities at Houston and Baytown, Texas; at Baton Rouge, La., and Hammond, Indiana, are the largest in the world. Virgin water-white H_2SO_4 from any processable acid we can pump out of barge, car or truck!

Sulphuric Acid is also shipped from Ft. Worth and Corpus Christi, Tex., LeMoyne, Ala., Los Angeles and Richmond, Calif., and Tacoma, Wash.

STAUFFER CHEMICAL COMPANY

380 Madison Avenue, New York 17, New York

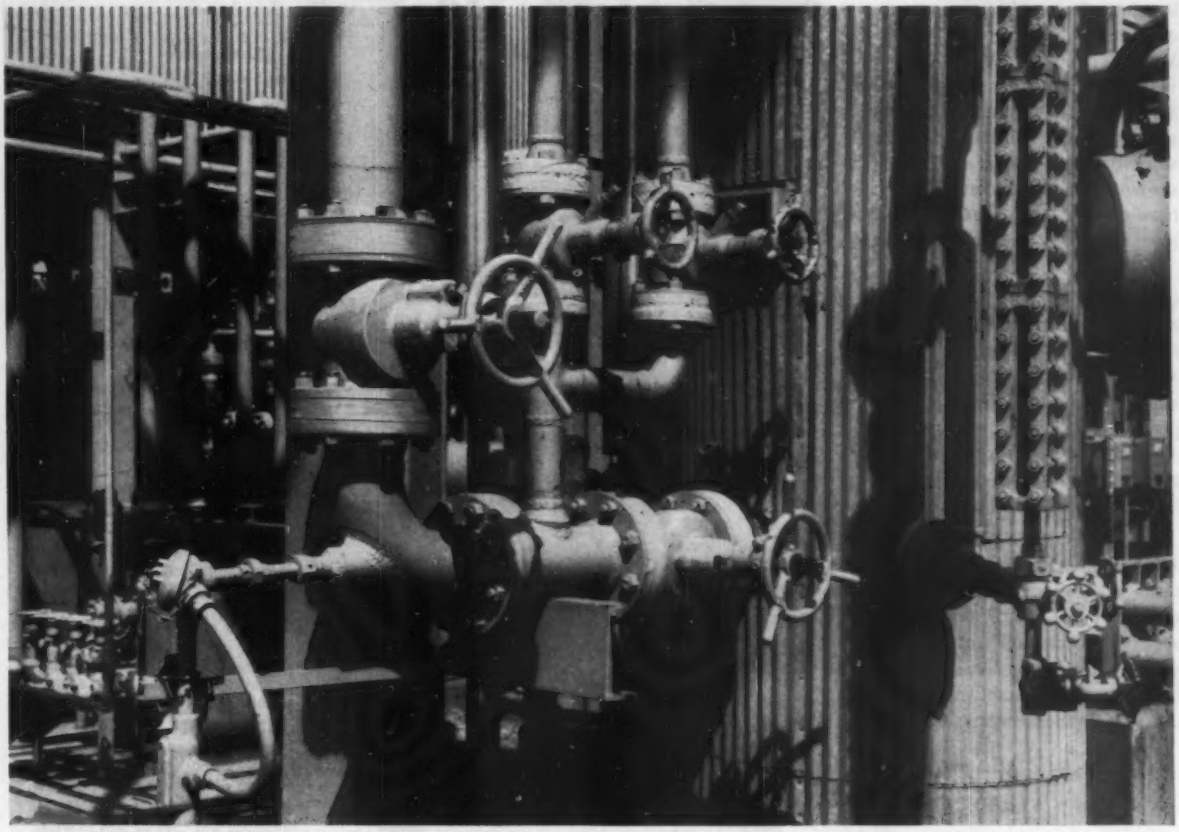
Prudential Plaza, Chicago 1, Illinois — 636 California Street, San Francisco 8, California

824 Wilshire Boulevard, Los Angeles 17, California — P. O. Box 9716, Houston 15, Texas

CONSOLIDATED CHEMICAL INDUSTRIES DIVISION, 6910 Fannin St., Houston 25, Texas

STOP PRODUCT CONTAMINATION BEFORE IT BEGINS BY USING ORBIT FORGED STEEL VALVES

Because of the non-lubricated positive closure seating principle used in the Orbit Valve, costly maintenance and the possibility of fluid contamination carry-over from valve lubricants which lower catalyst efficiency has been eliminated. Lubricant is not required for any part of the valve's mechanism that comes in contact with fluid being handled in cavity of valve.



Service shown here: Hydrogen Plant — Makeup Unit to Dehydrator.

Literature: Write Department B for Catalog 58-B and Service Manual No. 58.

Source: Available through your favorite industrial supply house.

ORBIT VALVES®

ORBIT VALVE COMPANY

P. O. BOX 699 • TULSA, OKLAHOMA • Phone LUther 4-4761 • TWX TU 925

For more data on advertised products, use Readers' Service Cards, last page.

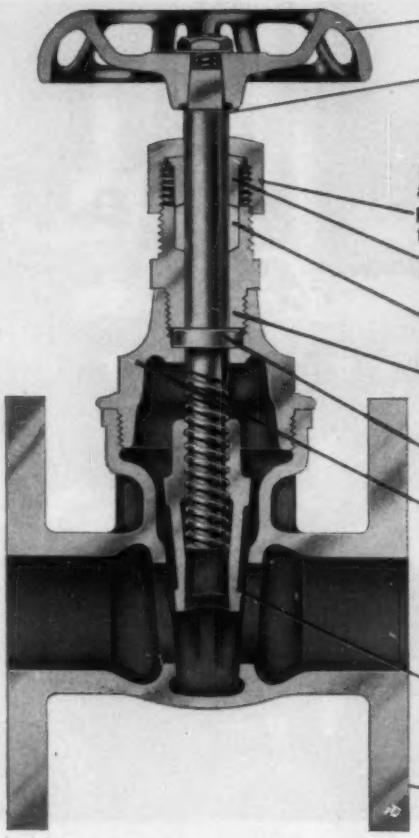
This dollar-saving **Solid Wedge Gate** shows it pays to

Specify JENKINS for STAINLESS STEEL Valves, too

BECAUSE Jenkins puts an extra-measure of quality in this Fig. 1300 Solid Wedge, Inside Screw Gate Valve you will find it satisfies the needs of many services for which a more costly type often would be used. Look at the many superiorities in design and construction shown here. You'll conclude that it's hard to beat Jenkins at making valves, no matter what the material.

But no picture can show the quality of the castings . . . the precision machining . . . the rigid inspection and testing that have gone into this valve. All of these are as important as design and metal alloys in assuring long, dependable, economical valve service. And, all of them are up to the peak standards for which Jenkins has been known for almost a century.

SEND FOR NEW CATALOG of Jenkins Stainless Steel Valves, in patterns and alloys that satisfy the requirements of practically all corrosive services. These Jenkins Valves meet valve industry specifications and the high standards established by leading users of stainless steel valves.



WHEEL of high strength malleable iron, designed for firm, cool grip and easy operation.

SPINDLE of large diameter and dense structure has high resistance to wear and torsion strains. The threads precisely machined to correct pitch and lead assure tightness, ease of operation and resistance to shearing stresses.

PACKING NUT is strong and deep for full thread engagement.

PACKING GLAND is a self-centering design to afford tightness without excessive friction on spindle.

PACKING — A Teflon ring in a large capacity box requires less frequent replacement.

PACKING BOX NIPPLE assumes thrust when closing valve. It is extra heavy, with hex flats larger than diameter of bonnet face to prevent leakage.

SPINDLE COLLAR, integral with spindle, is large and wide to resist thrust and shearing strains.

BONNET is a rugged unit, with accurately machined threads to assure tight joints with the body and packing box nipple. Top of wedge and corresponding face inside of bonnet are machined to insure perfect spindle alignment and backseating for repacking valve under pressure.

SOLID WEDGE is tapered equally on both faces. Lugs on sides of wedge engage guide ribs in body to reduce drag and minimize chatter.

BODY has best combination of wall thickness and shell design to withstand pipeline stresses. An integral seat minimizes corrosive attacks.

JENKINS VALVES

LOOK FOR THE JENKINS DIAMOND

Sold Through Leading Distributors Everywhere

JENKINS BROS., 100 Park Avenue, New York 17, N. Y.

☐ Send the new stainless steel valve catalog

☐ Have a representative call on me

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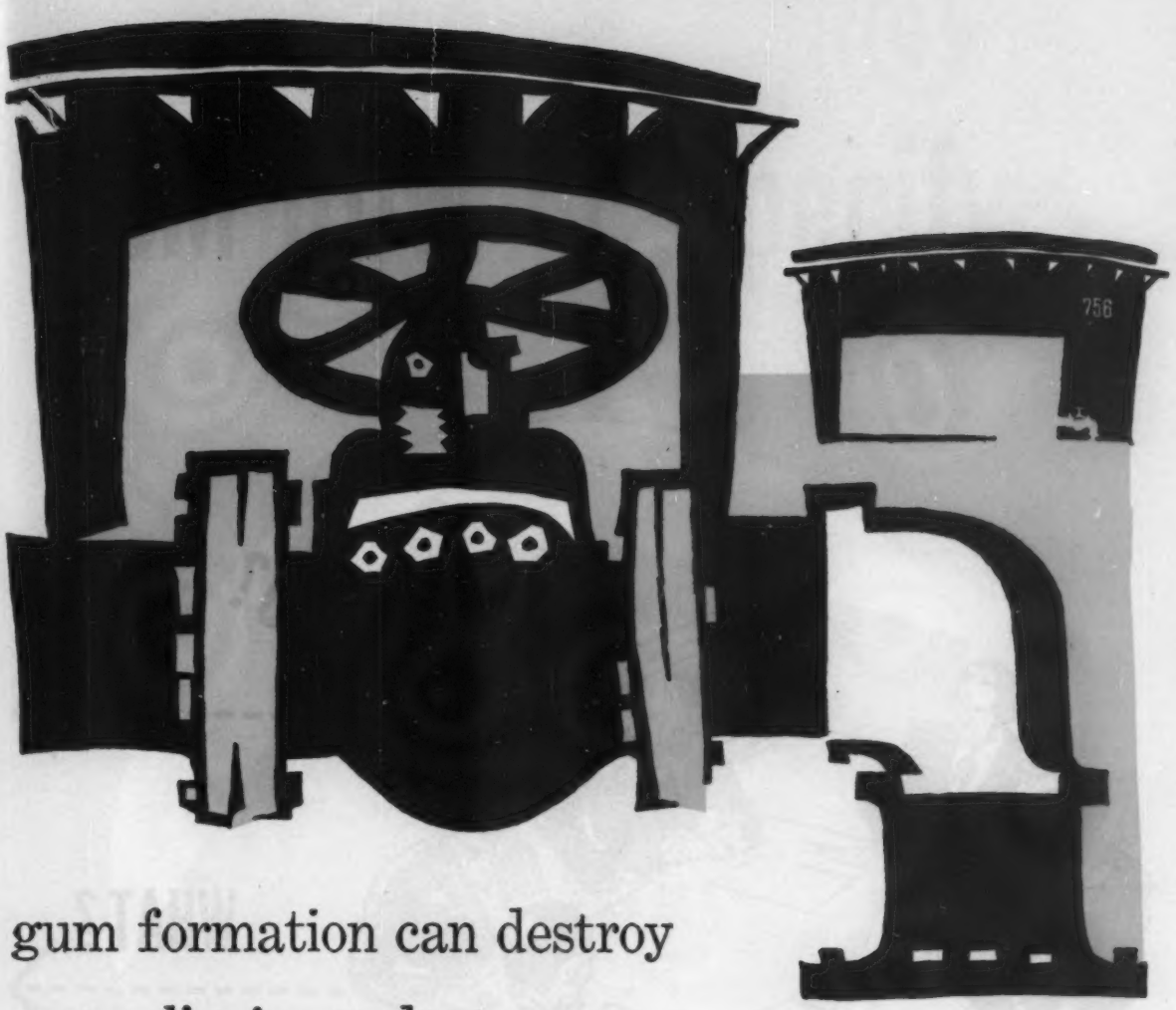
COMPANY.....

ADDRESS.....



gum formation can destroy
a gasoline's good name...
protect yours with **Tenamene** Eastman gasoline additives

Why *Eastman* gasoline additives? Three good reasons.

1 Eastman offers you every principal type of gum inhibitor in commercial use today.

2 Eastman, as a basic manufacturer of the additives it supplies, maintains complete control every step of the way, assuring you of a uniform product and consistent additive performance.

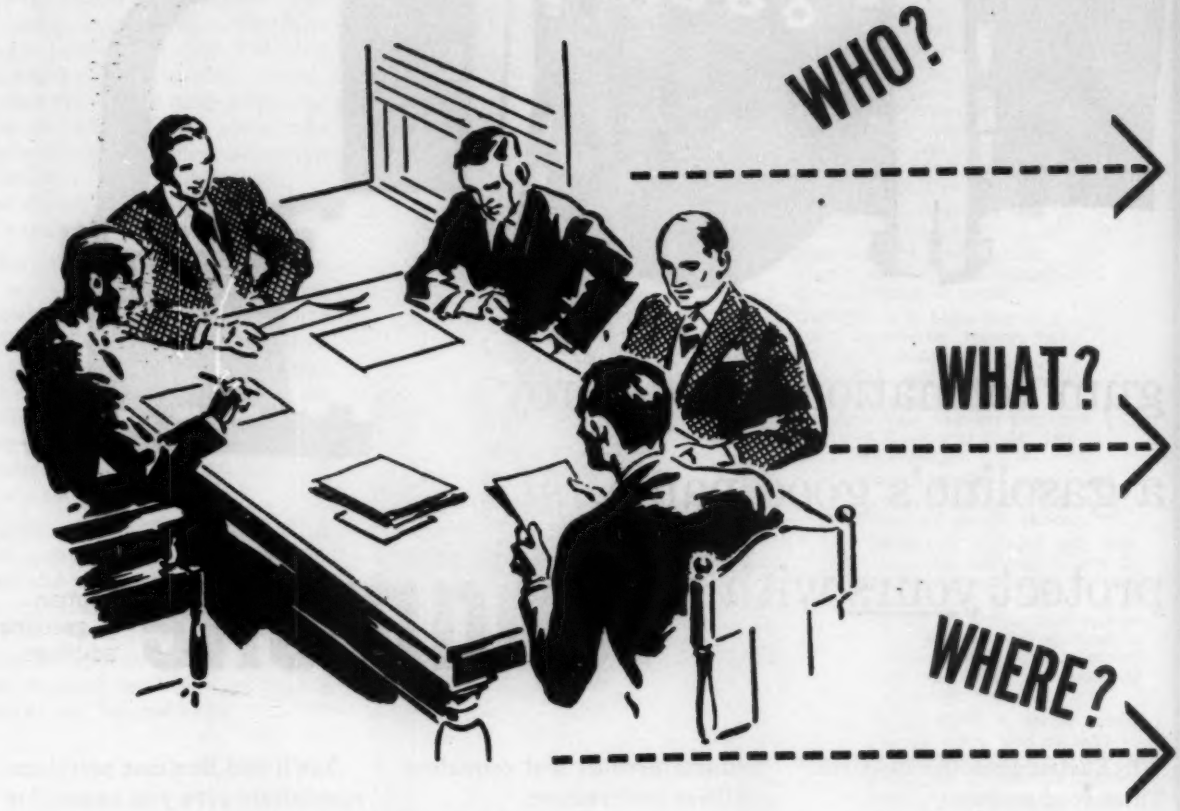
3 Eastman petroleum specialists provide in-refinery technical service to make certain you obtain the most efficient use of the additives you buy. Ask them, for example, about the cost-cutting possibilities of bulk delivery.

You'll find Eastman petroleum specialists give you unequaled technical service because inhibition of gum formation is their only interest. For further information, write EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE.

SALES OFFICES: Eastman Chemical Products, Inc., Kingsport, Tenn.; Atlanta; Chicago; Cincinnati; Cleveland; Detroit; Framingham, Mass.; Greensboro, N. C.; Houston; New York; St. Louis. **West Coast: Wilson Meyer Co.,** San Francisco; Denver; Los Angeles; Phoenix; Salt Lake City; Seattle.

For more data on advertised products, use Readers' Service Cards, last page.

With Men

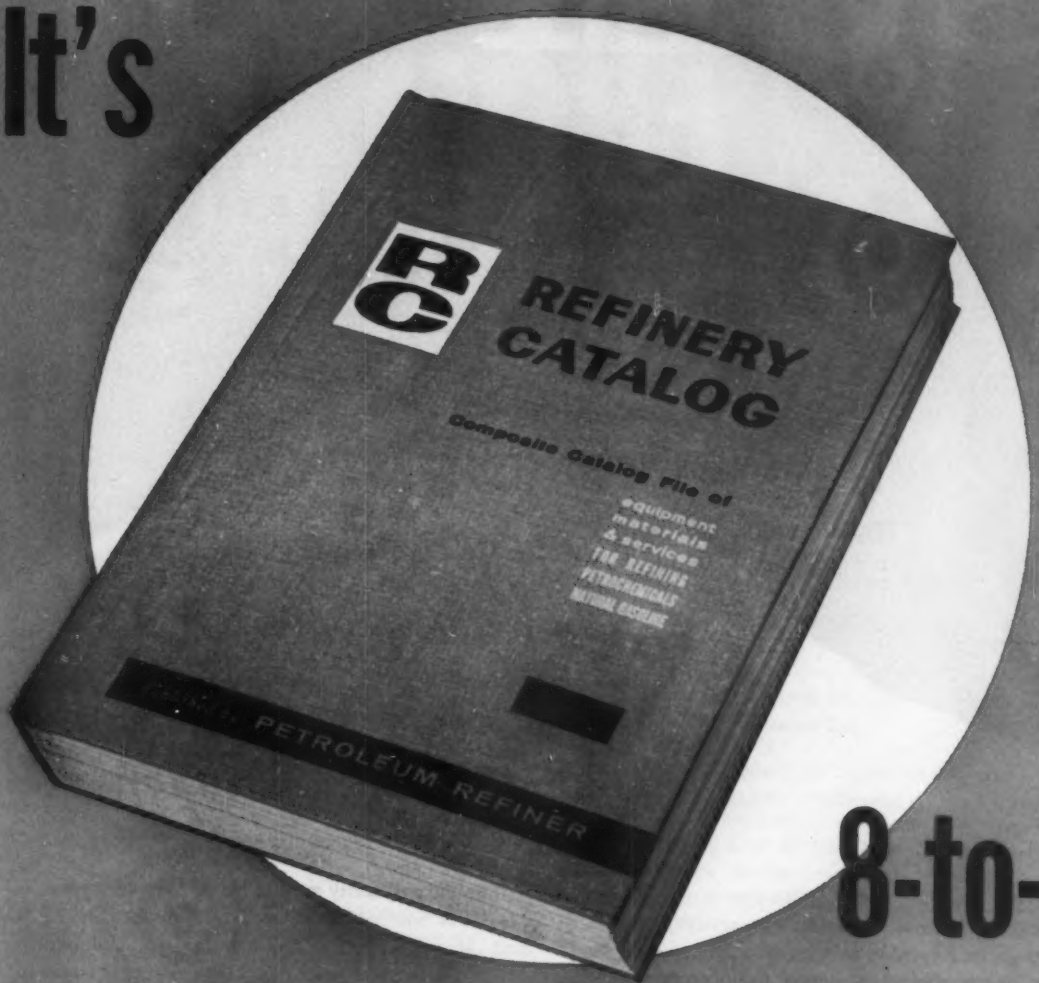


REFINERY CATALOG

Published by Petroleum Refiner

Who Buy And Specify

It's



8-to-1

HIGH PROFIT SULFUR FROM LOW PRICE PLANTS

Badger engineers help refiners convert H_2S... a by-product "nuisance"... to profitable elemental sulfur

There is a difference in sulfur plants — especially when you consider contractor services. Badger, through its Key Man Service, offers a *complete* design, engineering, construction and operation package. This proposal-to-product service plan provides you with a simple, functional plant that costs less to build and operate, produces high yields.

Badger's staff includes engineers who have been building successful sulfur recovery plants since 1948. Within the past thirty months plants have been completed for Socony Mobil Oil Co. (Paulsboro, N. J.) and Montana Sulfur & Chemical Co. (Billings, Mont.). Both plants were built at low cost to produce high profit sulfur economically.

If sulfur recovery is in your future, Badger belongs in your plans. For more complete information, write or phone today. Badger Manufacturing Company, 363 Third Street, Cambridge 42, Massachusetts.

***built by* BADGER**

INTERNATIONAL DESIGNERS • ENGINEERS • CONSTRUCTORS

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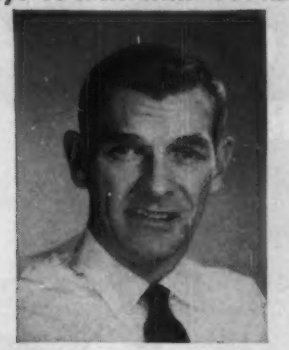
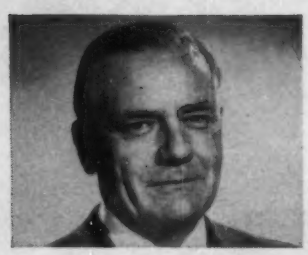
Paris, France

"I'm interested in boron trifluoride because it's an easy catalyst to work with" . . . Plant Superintendent



"I'm most interested in the high reactivity of boron trifluoride" . . . Research Director



"I've discovered that by using BF_3 we can simplify our plant designs" . . . Chief Engineer

What interests you most about Boron Trifluoride?

Whatever your reasons for investigating boron trifluoride, you'll find Baker & Adamson® is your best source of information. B&A has long been the leader in BF_3 research and production. B&A was the first to introduce boron fluoride etherate to industry . . . has shipped boron fluoride gas by tube trailer transport for many years—making it readily available in large commercial quantities. Today, B&A offers the widest range of BF_3 complexes, including ether, phenol, monoethylamine, other nitrogen and oxygen compounds. That's why—when it comes to BF_3 call on Baker & Adamson.

Useful product data bulletins

B&A has compiled extensive reference data on the use of boron fluoride gas and its complexes as efficient catalysts in organic synthesis. Boron fluoride's wide range of applications and its cost-cutting production advantages —such as its ease of catalyst removal—make it a factor to be considered in almost any organic synthesis problem. Write today for any or all of the free technical bulletins listed below:

TITLE	CODE No.
Boron Trifluoride, Compressed Gas	DA-34691
Boron Trifluoride, Compressed Gas Handling Information	TB-34691
Boron Fluoride Complexes with Nitrogenous Compounds	DA-3469-NIT-1
Boron Fluoride Complexes with Oxygen-Containing Compounds	DA-3469-OXY-1
Boron Trifluoride, Ether Complex, Tech.	DA-34711
Boron Trifluoride, Monoethylamine Complex, Tech.	DA-34661
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New book on Boron Fluoride

The most extensive study of boron fluoride to date is contained in a new book, "Boron Fluoride and its compounds as catalysts in organic chemistry," written by A. V. Topchiev, S. V. Zavgorodnii and Y. M. Paushkin. It discusses the use of boron fluoride as a catalyst in organic chemistry and also its derivatives and molecular compounds. Contents include physical and chemical properties; co-ordination compounds; compounds of boron fluoride in alkylation, polymerization, isomerization, cyclization, nitration and sulphonation reactions; condensation reactions in the presence of boron fluoride; and many other topics.

This book (price, $12) is published by Pergamon Press, Inc., 122 East 55th St., New York 22, N. Y.

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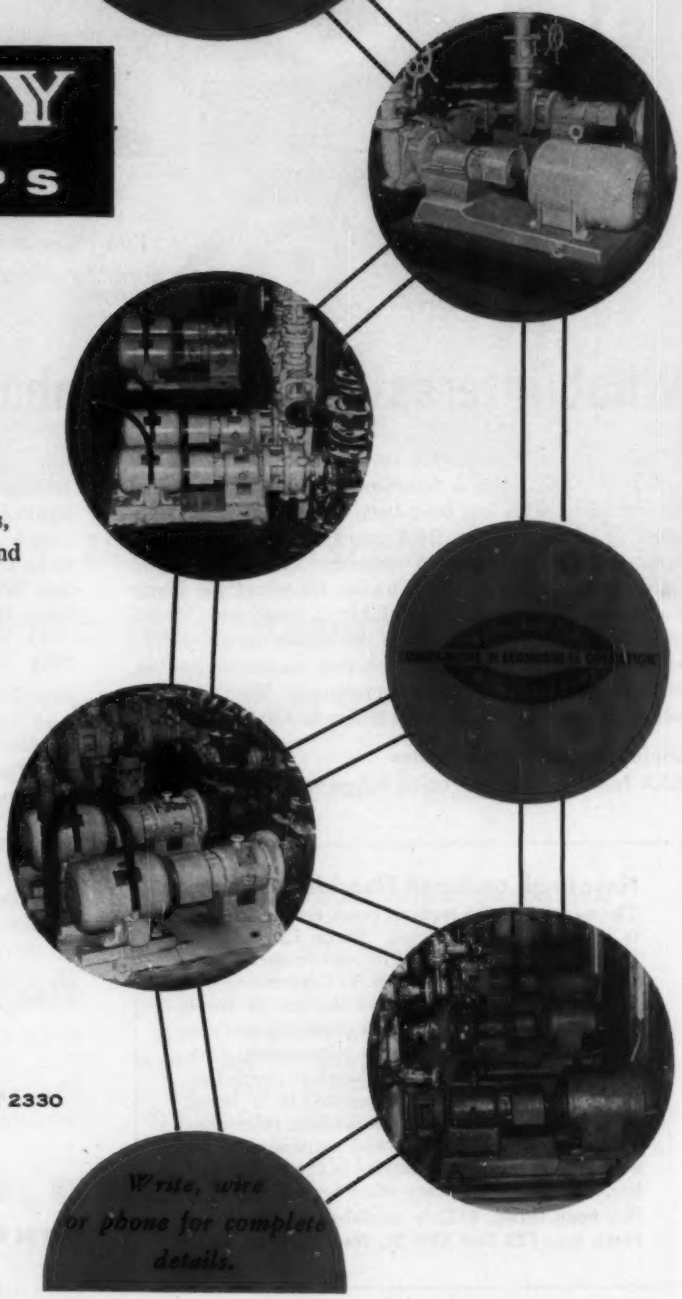

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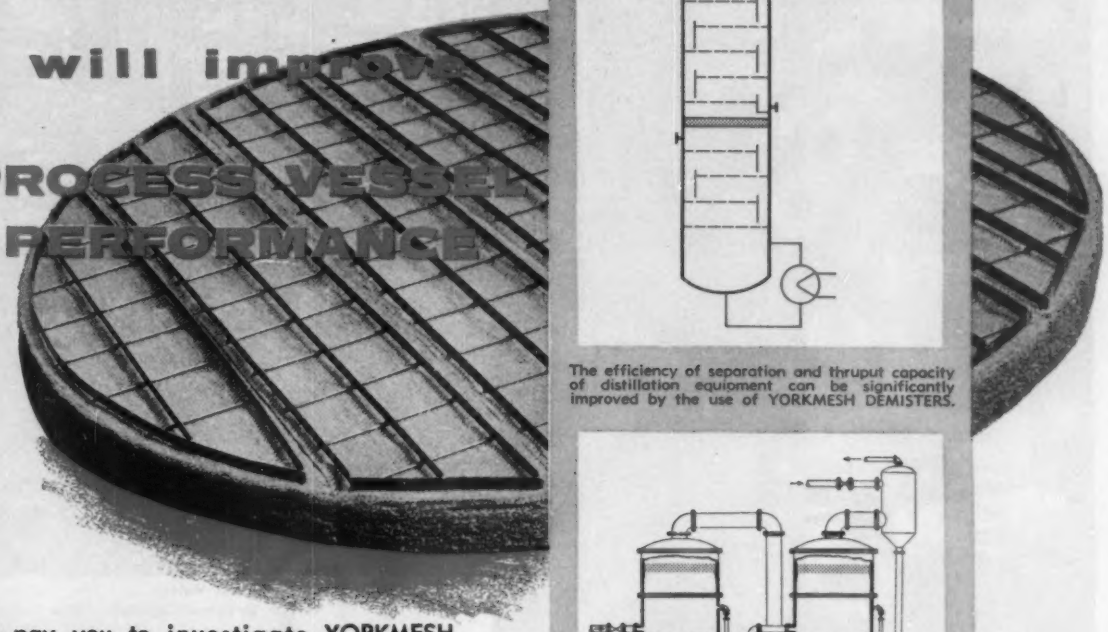
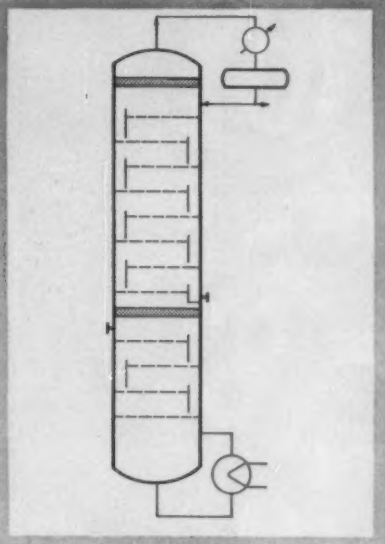
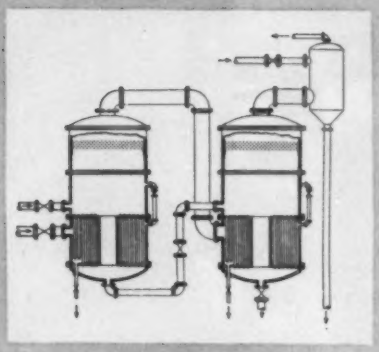
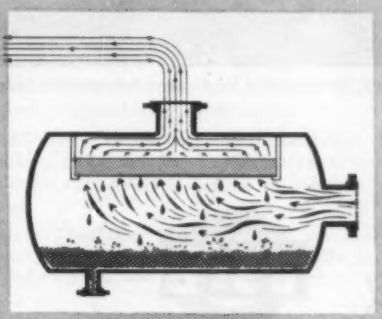




The efficiency of separation and thruput capacity of distillation equipment can be significantly improved by the use of YORKMESH DEMISTERS.



YORKMESH DEMISTERS installed in evaporators avoid product loss and provide clean condensate.



YORKMESH DEMISTERS installed in Knock-Out Drums result in high separation efficiency at low pressure drop.

It will pay you to investigate YORKMESH DEMISTERS if your process vessels need a lift in efficiency. The versatile knitted wire-mesh pads are being used more and more throughout industry to *stop* liquid entrainment and improve the performance of:

Vacuum Towers, Distillation Equipment, Gas Absorbers, Scrubbers, Evaporators, Knock-Out Drums, Steam Drums and many others.

Here is what happens when YORKMESH DEMISTERS are installed:

1. As vapor disengages from liquid it carries with it fine liquid droplets.
2. When the vapor stream passes thru the fine wire mesh, the liquid droplets impinge on the wire surfaces, coalesce in to large drops, and fall.
3. The vapor is now dry and free from entrained liquid.

Send us details on your type of process vessel or operation, vapor flow rate, pressure, temperature, and density or molecular weight; approximate amount of entrained liquid, viscosity, and specific gravity . . . for existing equipment advise dimensions, indicate vertical or horizontal vessel and material of construction required for mesh and grids. Complete details will make it possible for us to present our recommendations and quotation.

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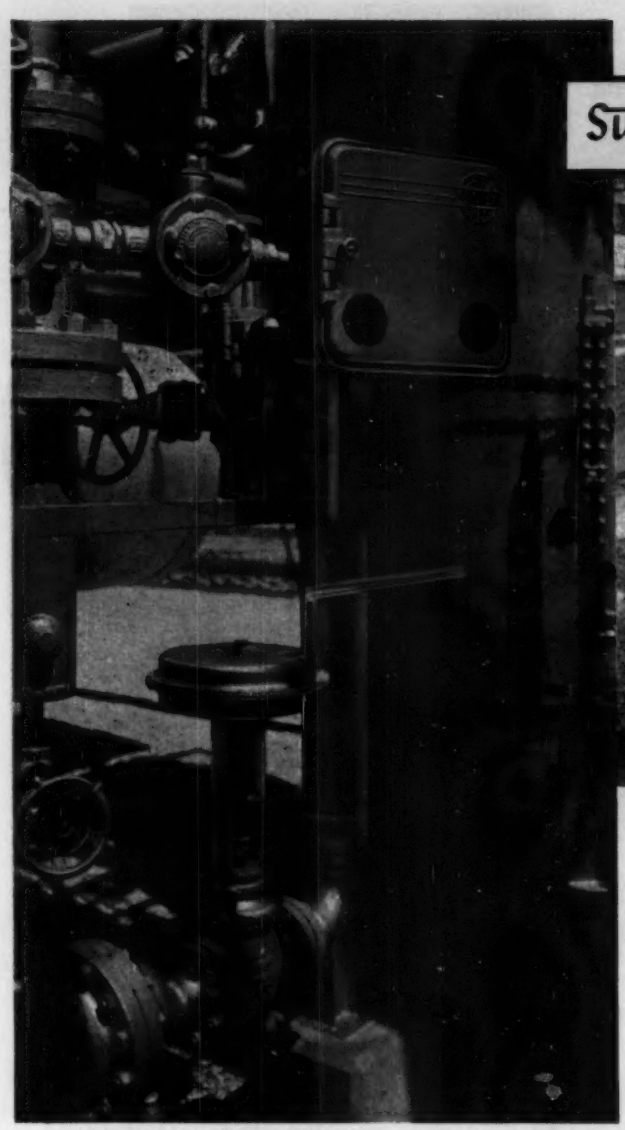

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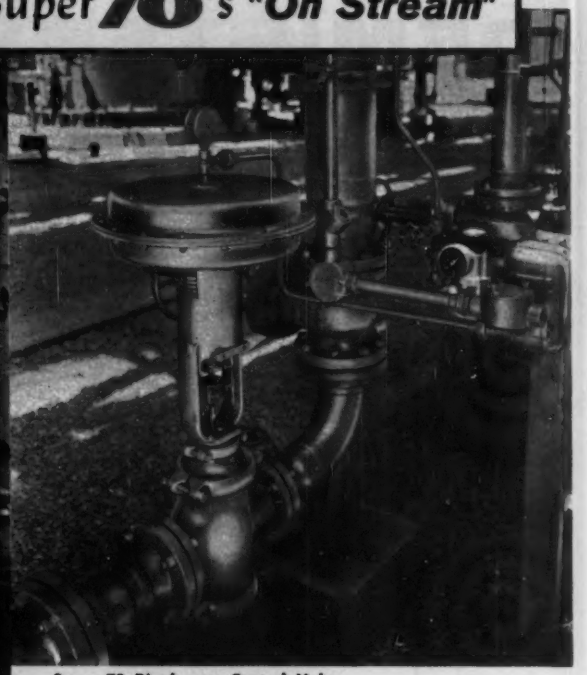
Super 70's "On Stream"



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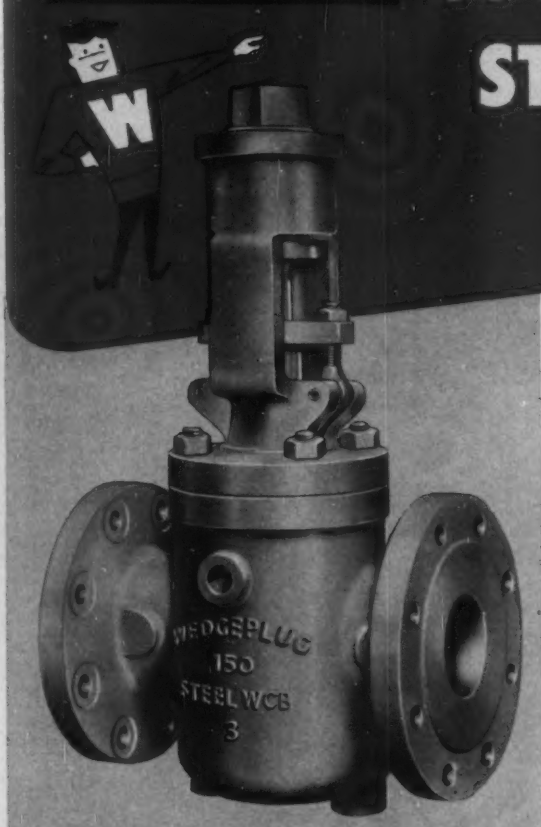

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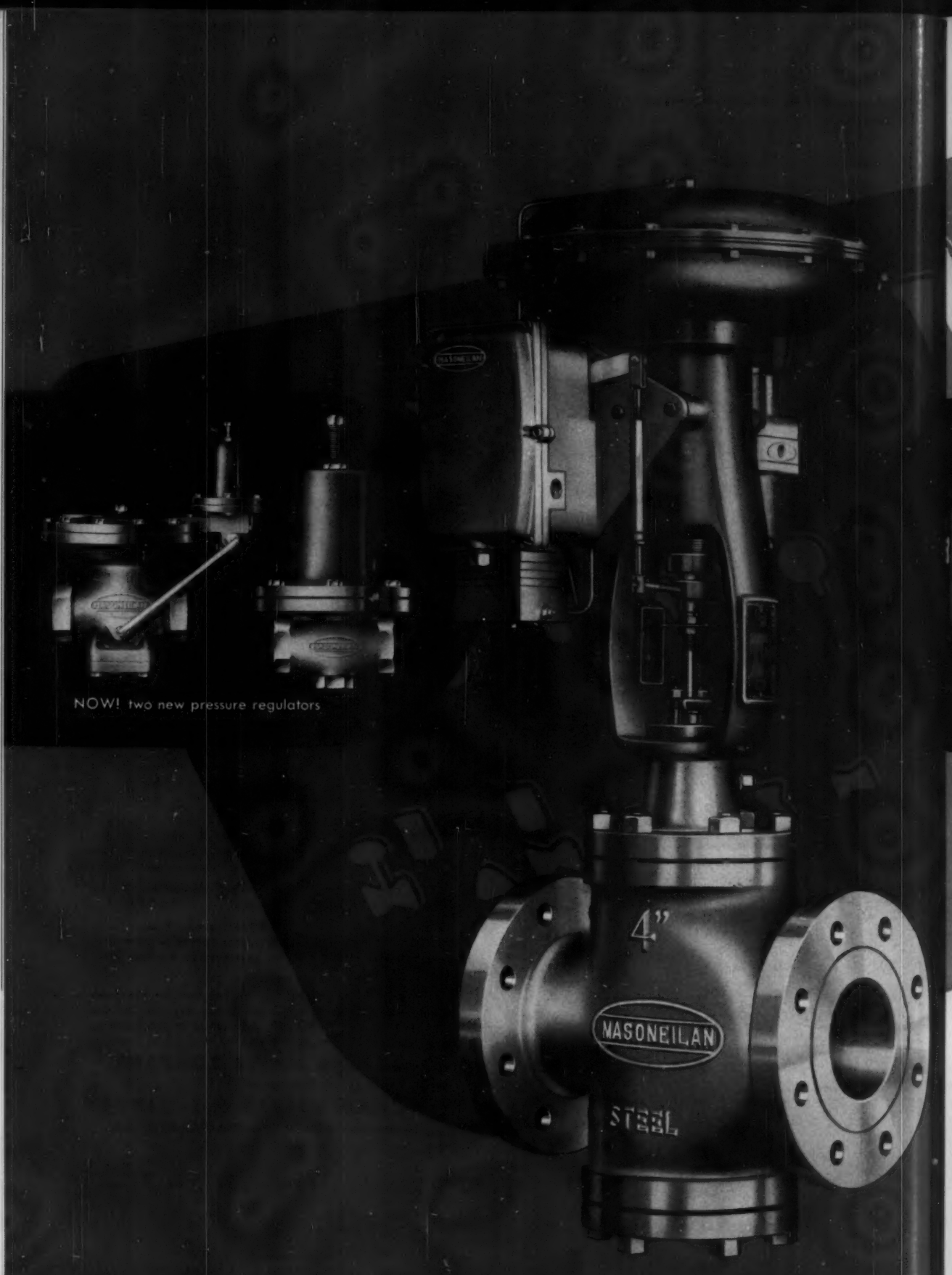

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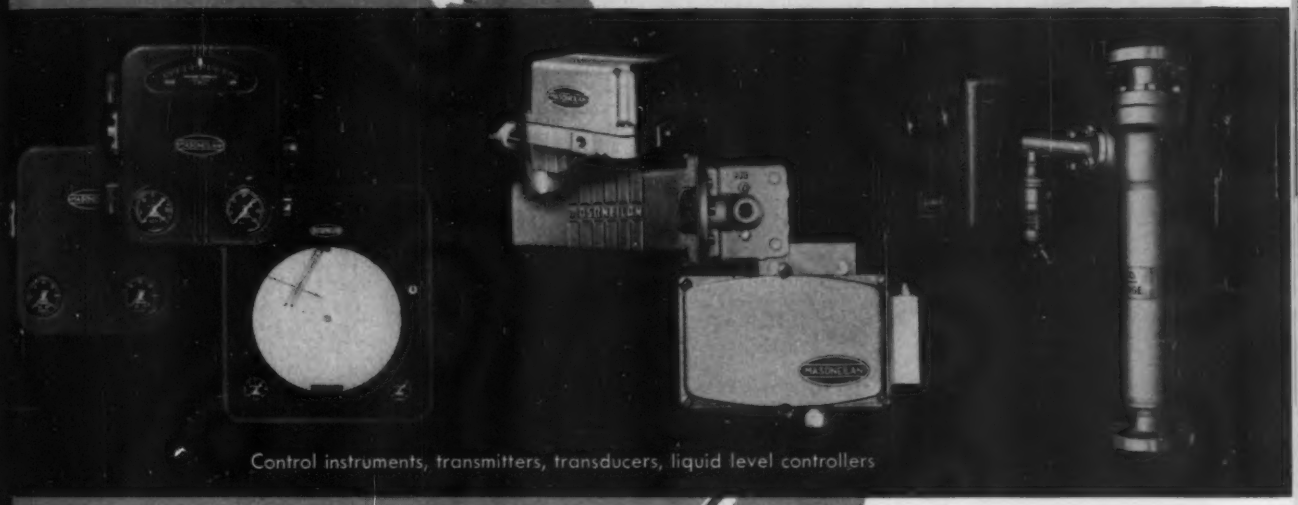

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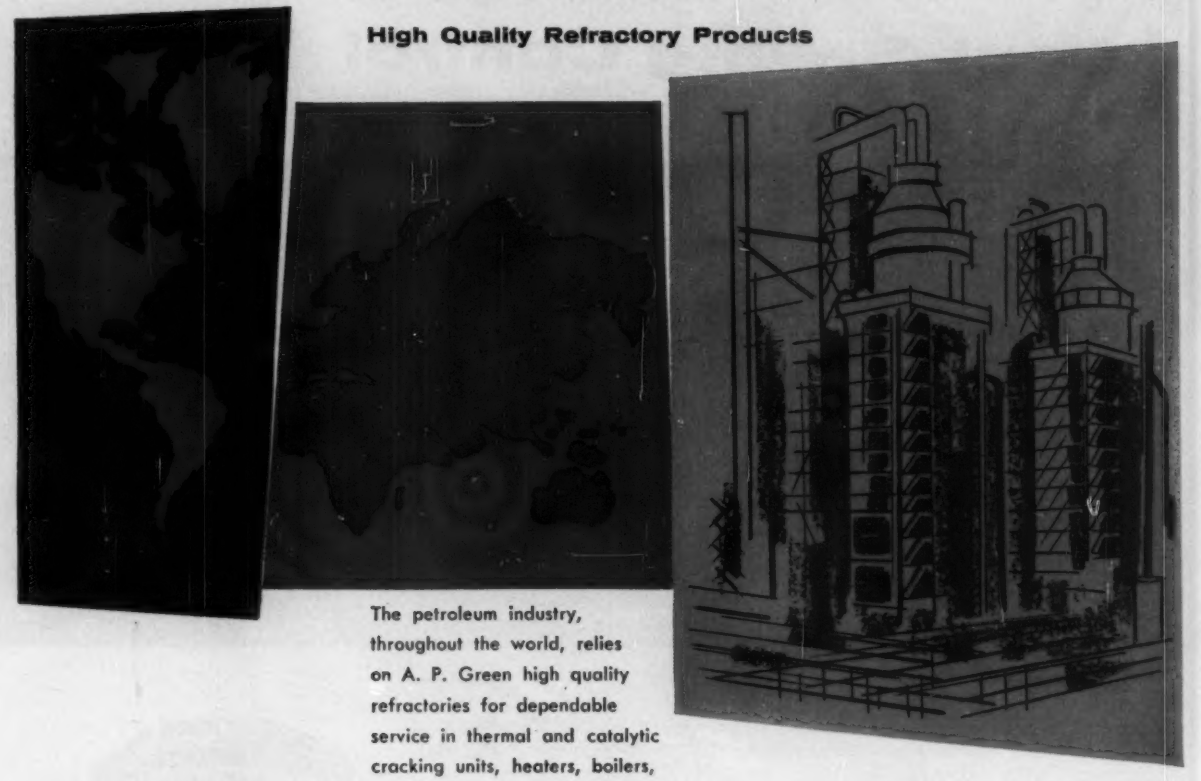

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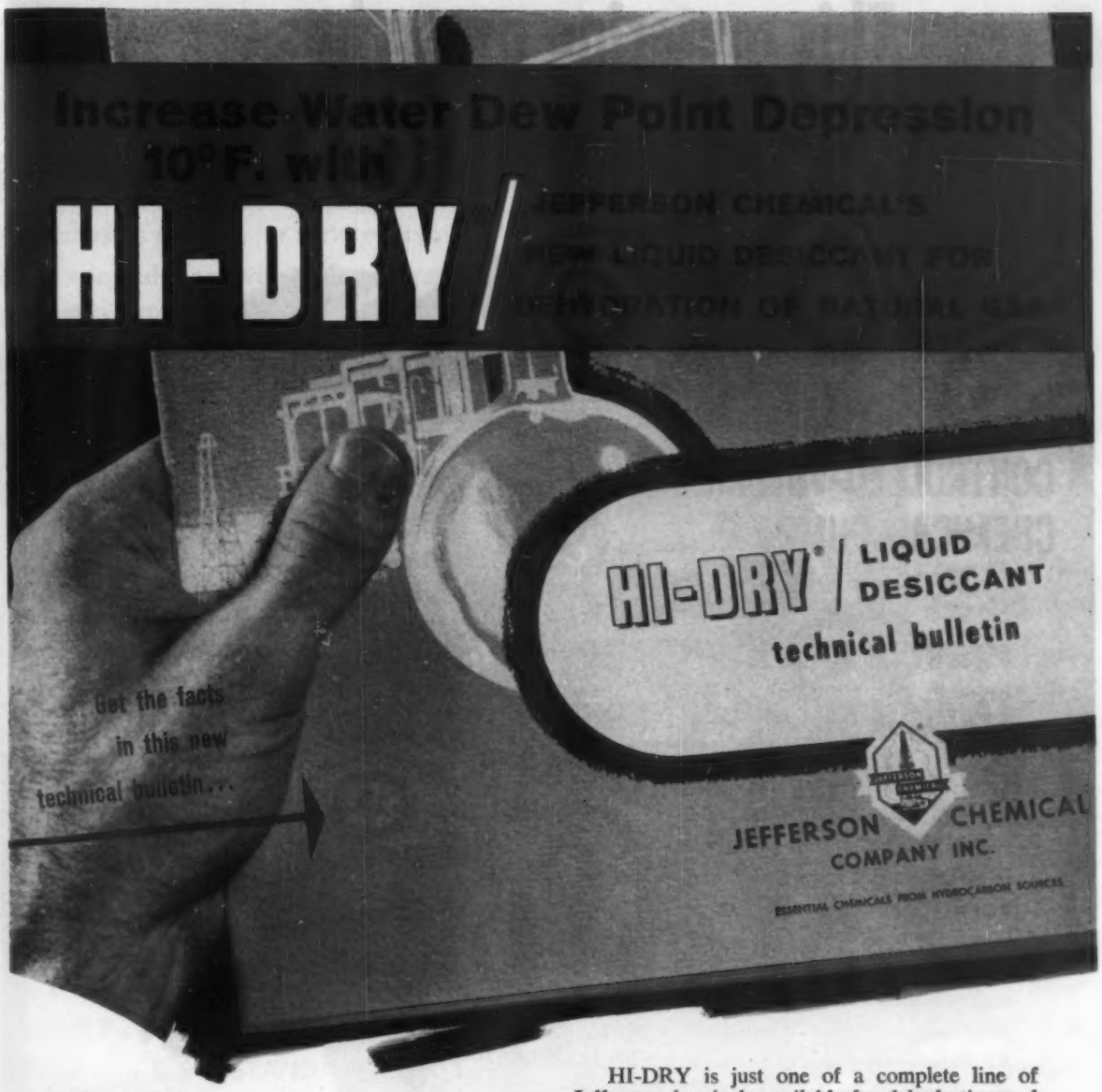

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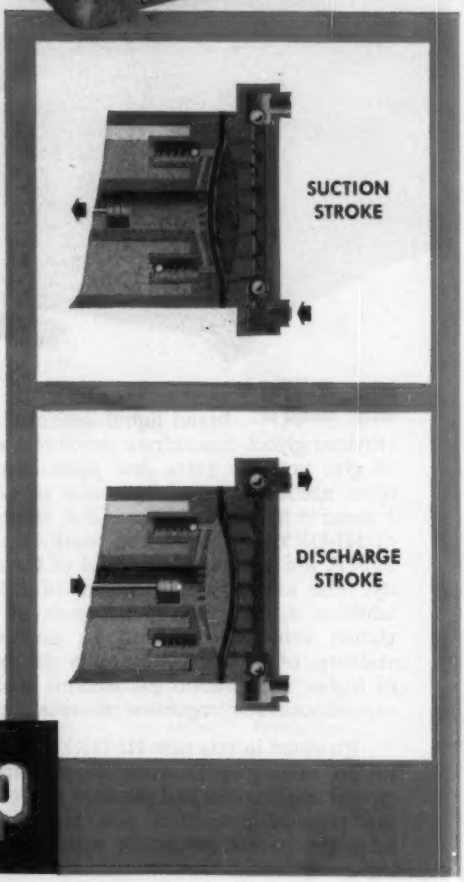

WRITE FOR BULLETIN 440 containing typical applications, flow charts, description and specifications of models of various capacities and constructions and special leakage chart. Lapp Insulator Co., Inc., Process Equipment Division, 3409 Poplar St., Le Roy, New York.

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Aglow with brilliant colors symbolizing an almost endless variety of processed chemicals, a large flask, at left, reflects the atmosphere of its refinery background. Dresser Industries, by improvement of existing lines and development of new equipment, have made many contributions to the progress of the refining and processing industries. Dresser companies provide superior products and technical services which have long been known as the standard of comparison the world over.

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This new 800 T/D Platformer built for Deutsche Shell at Hamburg-Harburg, Germany, is typical of the many petroleum, petrochemical and chemical processing units for which Procon has been selected to handle construction.

Whether your plans call for additional process facilities or an entire new plant, Procon's world-wide organization can provide complete service from blueprint to finished job. Handled by Procon, your new facility will be built to perform efficiently, economically . . . and as intended.

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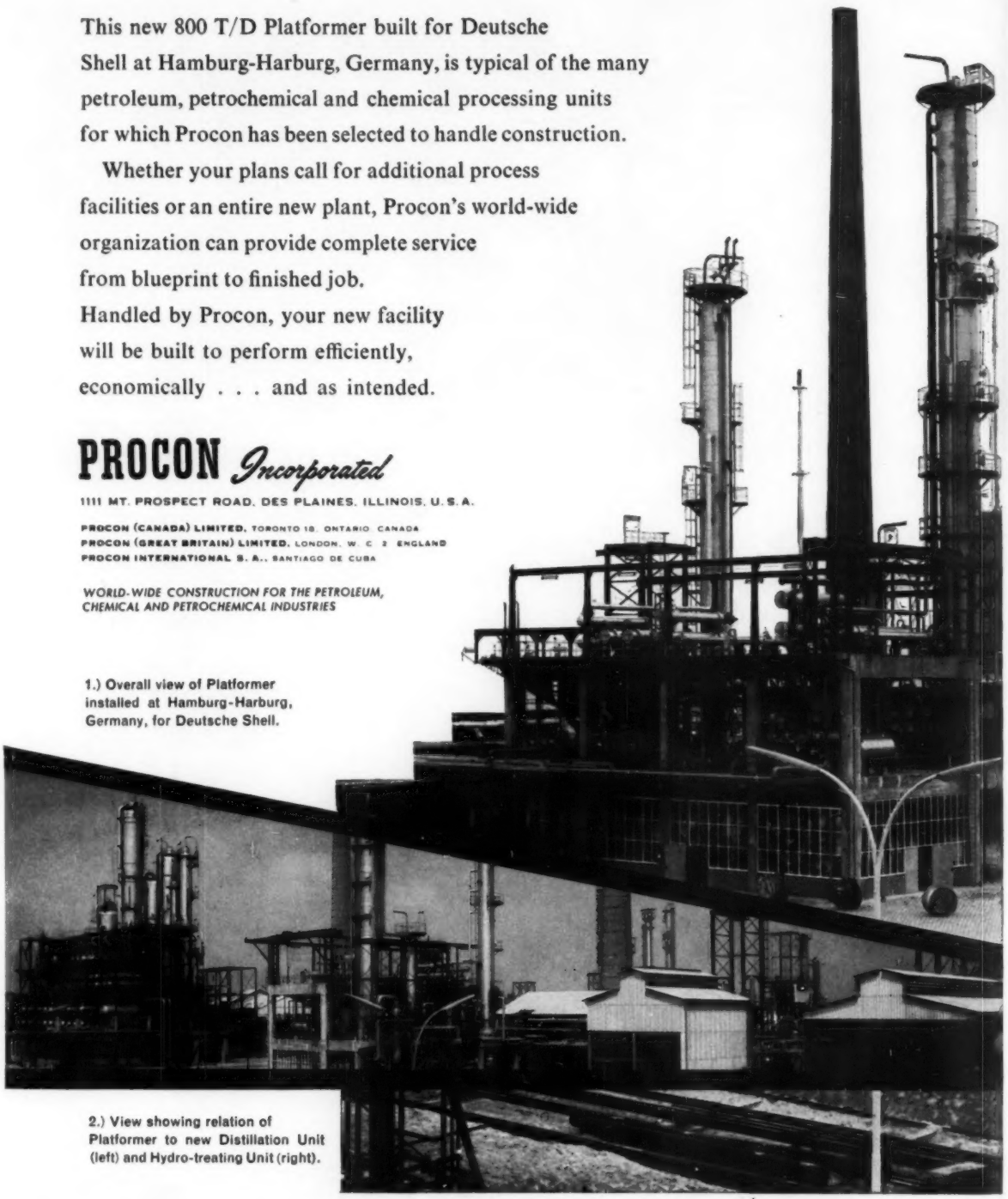

1.) Overall view of Platformer installed at Hamburg-Harburg, Germany, for Deutsche Shell.

2.) View showing relation of Platformer to new Distillation Unit (left) and Hydro-treating Unit (right).

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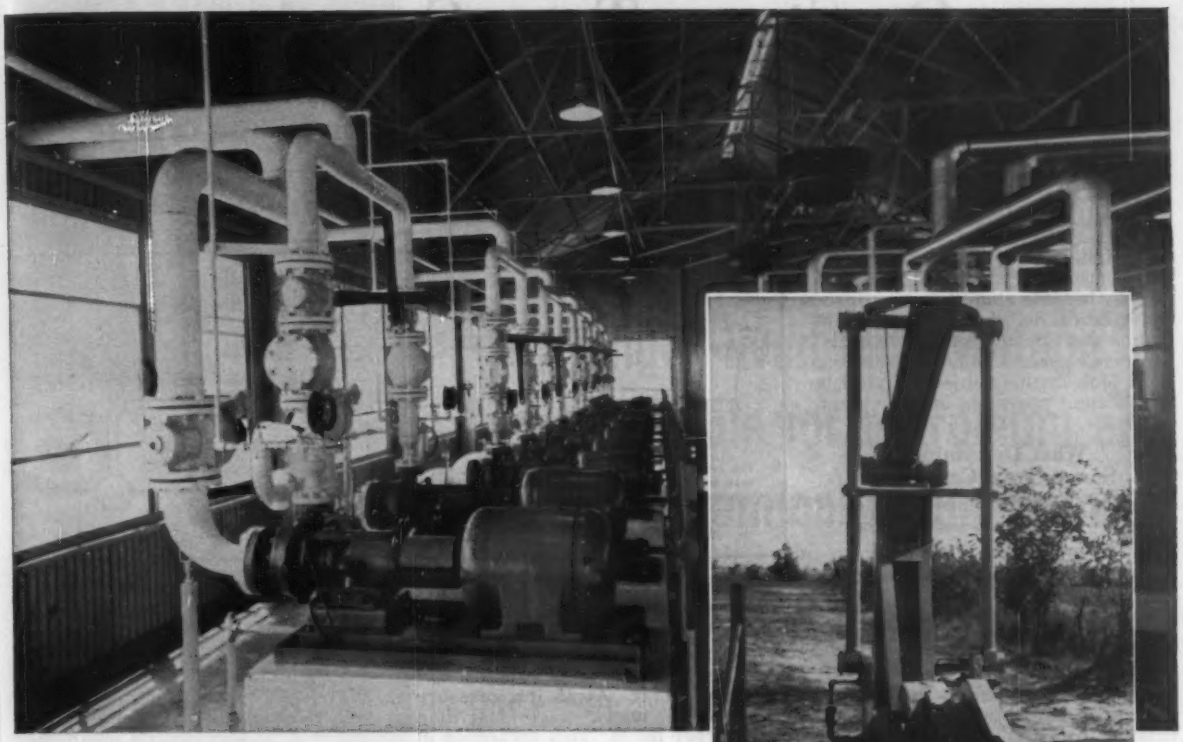
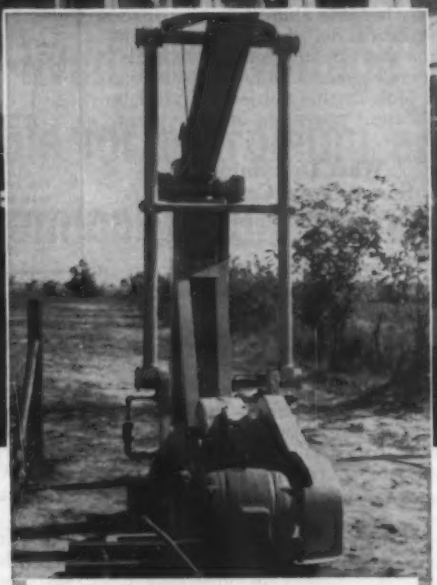


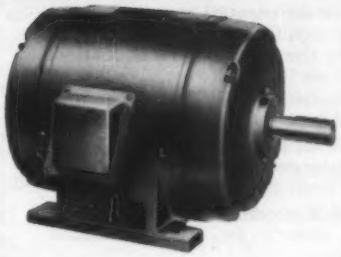


WAGNER Petroleum Industry Motors cut operating costs in *FIELD* and *REFINERY*

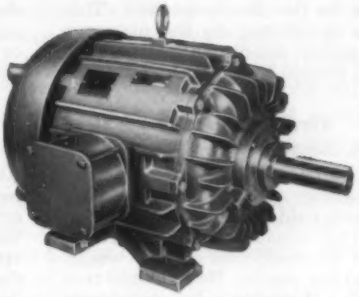
Wagner Type DP and DY Motors are especially designed to meet the load conditions of oil well pumping—to give cost-cutting, year-round, maintenance-free outdoor service. Corrosion-resistant cast iron frames and endplates protect the motor from rain, sand and snow. Conduit boxes are moisture proof and dust-tight. These motors are available for either polyphase or single phase operation. You can get them from stock in your immediate area.

You cut costs when you install Wagner Type JP explosion-proof motors in the refinery because these are built with *extra protection* that means longer motor life: the vital parts of the motor are sealed against dust, fumes, and moisture—the cause of most motor maintenance problems. These motors are approved for Class 1, Group D hazardous locations.

For full information, write for Bulletins MU-224 and MU-137, or phone your nearby Wagner branch office.



Type DP or DY oil well pumping motor. Single phase or polyphase.



Type JP standard totally-enclosed, in ratings through 250 hp; and Type ZP tube ventilated, in ratings through 500 hp.

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Some Straight Talk On Steam Trap Capacity

... or pulling away the curtain of confusion that surrounds steam trap capacity ratings.

Unfortunately, for the steam trap buyer, the subject of steam trap capacity has become cloudy and confused by a landslide of claims, counterclaims and inconsistent "standards" for measurement. So let's take a cold hard look at this subject so vital to the efficient operation of your plant.

What Determines Steam Trap Capacity?

There are three factors that determine the capacity of a steam trap:

1. The area of the orifice.
2. The density of the condensate.
3. The pressure differential across the trap.

Let's take a closer look at each of these:

Area of orifice is usually specified by the trap manufacturer or can be calculated from the diameter. Nothing complicated here.

Density of condensate depends on temperature. A cubic foot of cold water weighs 62.4 lbs. At 250° F. or 15 psi, it weighs less than 59 lbs. This is important. Don't overlook it.

Pressure differential across the trap is most significant. And it is complicated by the many factors that affect it, such as:

1. Pressure drop between unit drained and the trap when the trap valve is open.

2. Distance the trap valve is moved from the valve seat.

3. Back pressure on the trap with orifice closed; i.e., return header pressure.

4. Increase in back pressure produced by condensate and flash steam flowing in the discharge line. This in turn is affected by the diameter and length of the discharge line, plus friction caused by valves and fittings.

Orifice Capacity Vs. Steam Trap Capacity

Figure 1 shows a ½" diameter sharp-edged orifice at the end of a pipe filled with cold water at 15 lbs. pressure. The capacity of this orifice, using a .61 coefficient of flow would be 8,800 lbs. per hr. Now, would this ½" orifice if used in a ¾" steam trap installed as shown in Figure 2 provide the trap with a continuous discharge capacity of 8,800 lbs. of hot condensate per hour? The answer is "no". And here are some of the reasons why:

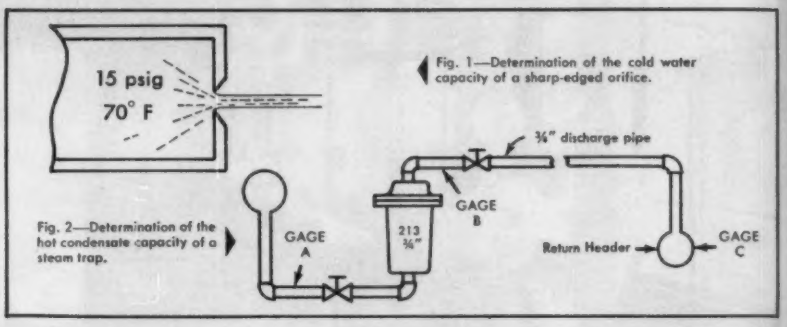

Fig. 1—Determination of the cold water capacity of a sharp-edged orifice.

Fig. 2—Determination of the hot condensate capacity of a steam trap.

Density of condensate. As pointed out above, cold water weighs 62.4 lbs. per cu. ft. At 15 lbs. pressure and 250° F. water weighs less than 59 lbs. per cu. ft. This difference in density alone reduces the lbs. per hour capacity of the orifice by over 5%.

Pressure differential across the trap. With the trap valve closed we have a static pressure differential of 15 psi. The trap valve must be able to open against this pressure. However, this is not the pressure differential that will determine the capacity of the trap valve.

The ¾" discharge line will be full of a mixture of flash steam and condensate. To keep this mixture flowing from the trap outlet to the return line requires a pressure differential. In actual capacity tests run as shown in Figure 2 Gage B at the trap outlet registered 11 lbs. back pressure. Thus the true pressure differential across the trap was about 4 lbs. Under these conditions the measured capacity of the trap was 4,340 lbs/hr. or just about half of the capacity of the ½" orifice for cold water.

How Armstrong Determines Capacity Ratings

Armstrong trap capacity ratings are based on hundreds of tests under actual operating conditions. In these tests, the condensate used was at the steam temperature corresponding to the test pressure. Thus, the capacities determined take into account the pressure drop that occurs when the trap orifice opens and the choking effect and back pressure of the flash steam. Actual installation hookups were used so that pipe friction in both inlet and discharge lines as well was reflected in the results.

Let's go back to the example cited above and in Figure 2. The trap referred to is an Armstrong No. 213. While it did test out at 4,340 lbs. per hour for a static pressure differential of 15 psi, it is rated in the catalog at only 3900 lbs. per hour for this pressure—just to be on the safe side.

For the trap buyer, this means that Armstrong Steam Trap capacities are based on handling condensate at steam temperature for the stated static steam pressure differential under actual working conditions.

Capacity ratings which don't take into account all of the variables will be misleading and may lead to the selection of undersized traps. So whenever you specify or buy traps be sure that the capacity ratings you work from are realistic. One way to be sure is to select Armstrong Traps with *guaranteed* capacity ratings.

* * *

Additional information on trap capacity ratings, plus data on how to correctly size, install and maintain steam traps for any pressure, any temperature and any load, are presented in the 48-page Armstrong Steam Trap Book. Ask your local Armstrong Representative for a copy or write:

Armstrong Machine Works
8525 Maple Street
Three Rivers, Michigan

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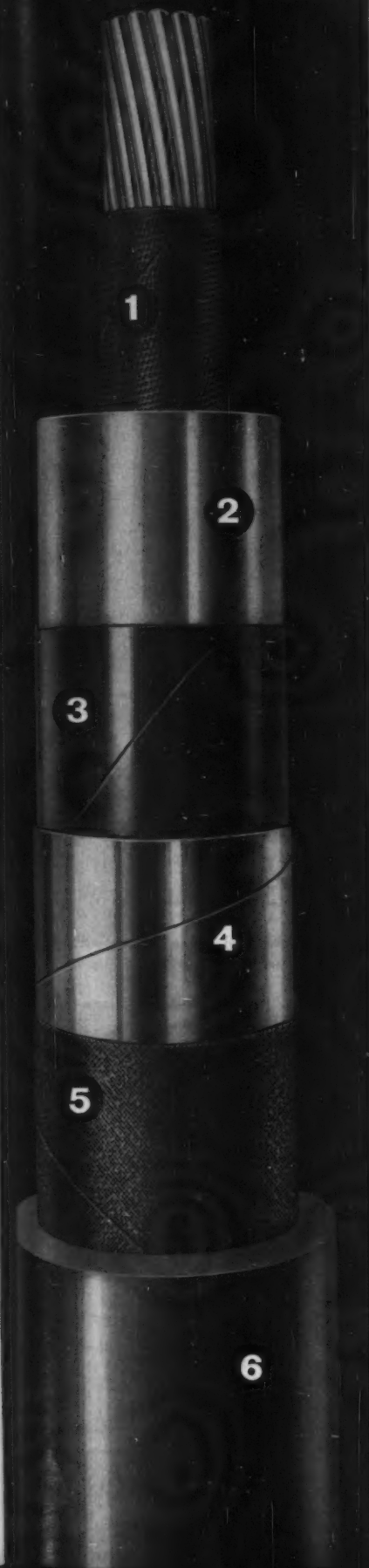

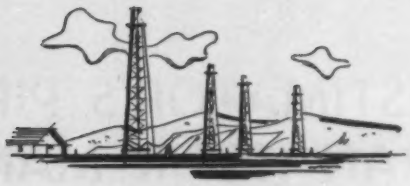

How Okonite makes a longer-lived high voltage power cable for petroleum and petrochemical applications

This Okolene 405 shielded power cable—developed by Okonite—is especially suited to petroleum and petrochemical applications, where petroleum products and chemicals can produce severe environmental conditions.

These constructional details, backed by Okonite's 80 years of manufacturing dependable cables, make Okolene 405 the best power cable developed to date for petroleum and petrochemical use up to 35kv.

1. The copper conductor is covered with a layer of Semicon* semi-conducting tape. This eliminates internal corona that could lead to dielectric failure.

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5. A cable binder tape is applied over the metallic shielding tape to assure the flexibility needed for easy handling.

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7. The finished product, checked against all quality control standards during manufacturing, is put through its paces in Okonite's modern final-testing laboratory, and is ready for years of service in your plant.

For the full story on Okolene 405 shielded high voltage power cable, ask your Okonite representative—or write for free Bulletin **PR**—2125 to The Okonite Company, Subsidiary of Kennecott Copper Corporation, Passaic, New Jersey.

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Using the above experience, the authors have devised an accurate and convenient method of estimating direct labor for complete fabrication and installation of process piping for any given system. Thus, by means of this manual, the reader has a method of obtaining a production efficiency percentage by applying all known local conditions and variables . . . plus a method of obtaining a complete direct labor rate for the craft or crafts involved in the various operations.

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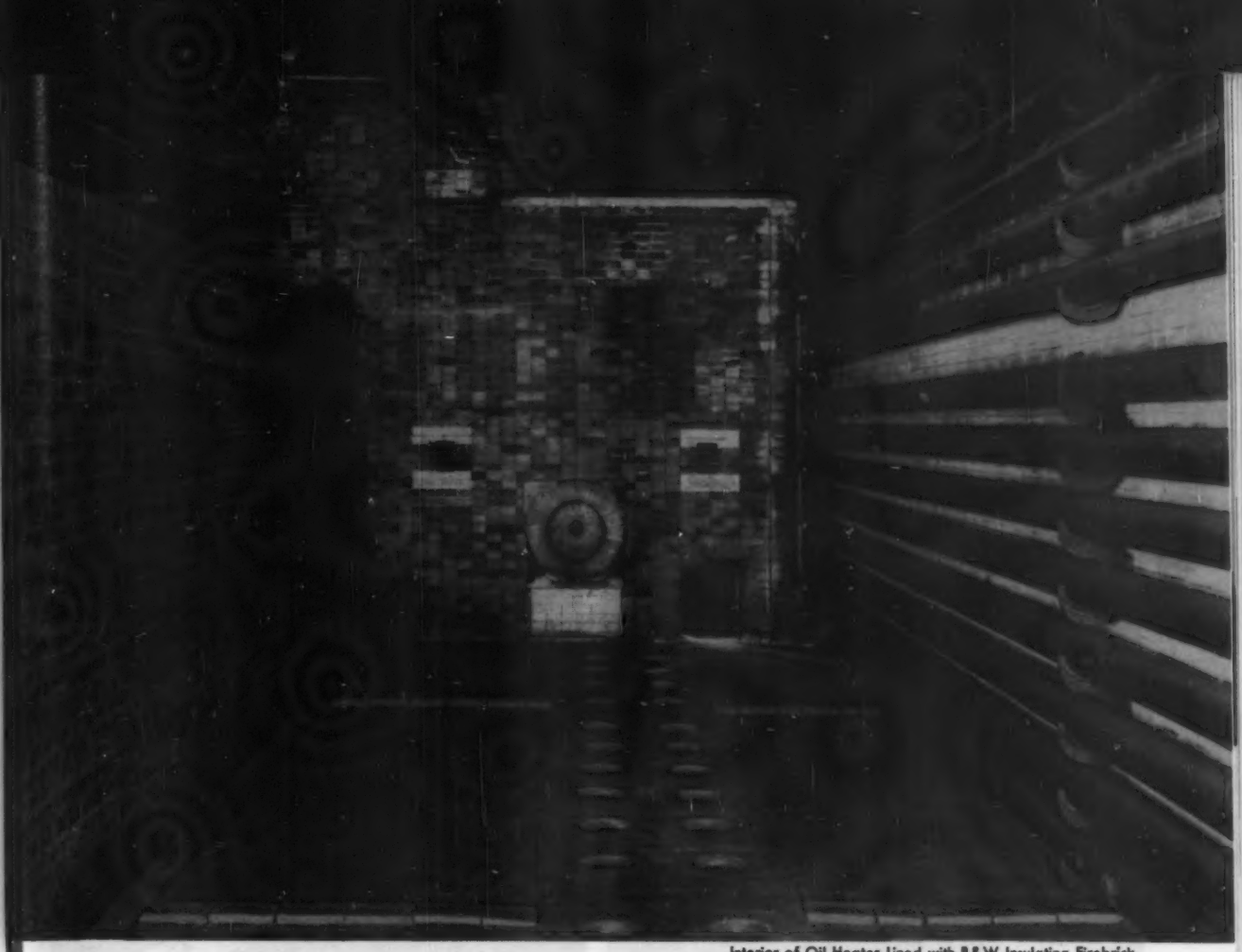

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Long refractory life, low furnace maintenance, and dependable service result from the use of B&W Refractories. B&W offers a wide line of *specialized* refractories *engineered* to give you maximum furnace availability and economy.

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Consult your B&W Refractories Representative for assistance with your refractories problem or write to The Babcock & Wilcox Company, Refractories Division, 161 East 42nd Street, New York 17, N. Y.

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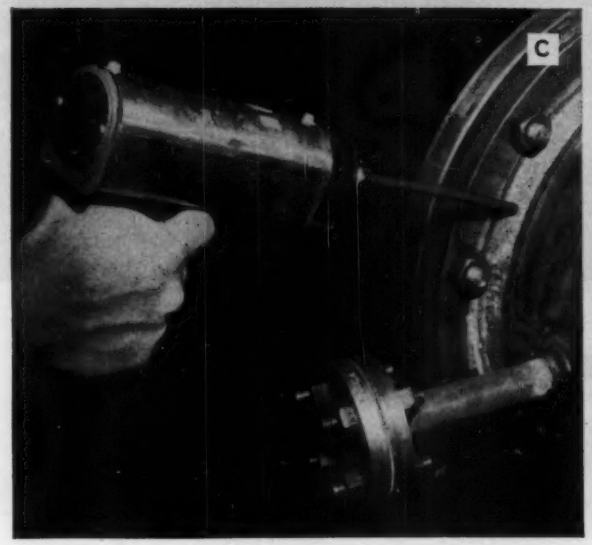

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Whatever is new in metallurgy, welding, or testing is sure to absorb the attention of Downingtown experts—especially when it helps us produce better processing equipment for you. Here are some of the modern techniques you would see on a trip through our shop. Write for handy index to the ASME Code.

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D **A penetrating analysis**—Special dye, sprayed on weld after back-chipping, reveals microscopic cracks so they can be eliminated before weld is completed.

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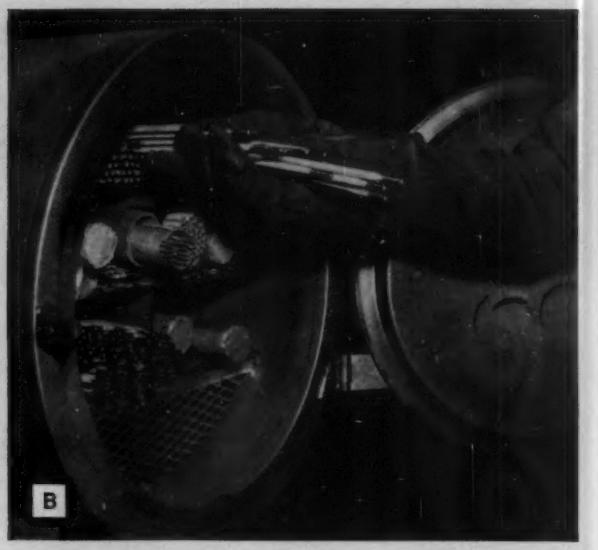

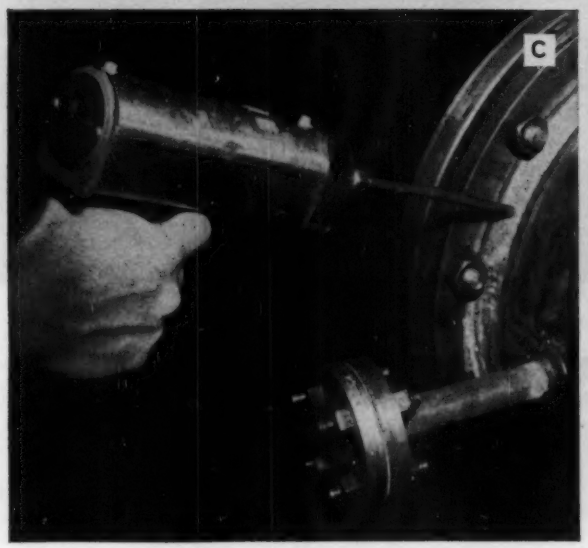

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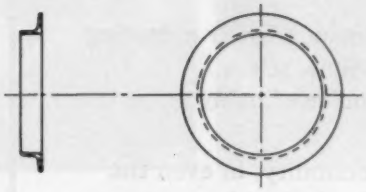

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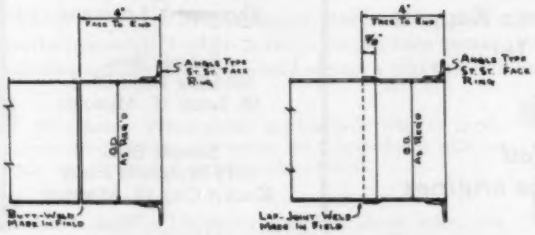

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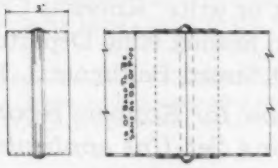

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- Forged steel body and union nut
- Stem, heat treated to 375 BHN
- 30% stronger rolled stem threads
- High temperature packing
- Cadmium plated bonnet, gland and gland nut
- Heavy duty air furnace malleable handwheel

The FIGURE 50 (at left) . . . a compact, bonnet-less valve, especially designed for instrument service

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FIGURE 100A and FIGURE 50A — with 18-8 stem
FIGURE 100B and FIGURE 50B — all 18-8 construction

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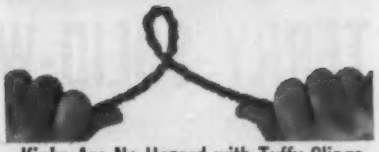
During a recent 12-months' period lost-time back injuries reported in one state (California) totaled 32,643. Lost-time injuries caused by strain or over-exertion: 24,639. A high price to pay—in misery and money—for lifting, pushing or carrying loads. Medical aid and compensation costs of materials handling accidents run far into the millions every year. Proper hoisting equipment, properly used and maintained, is one important answer to this problem. It may save your workers disabling injury, and save you expensive absenteeism and lost production.

Rules for Safe Use of Hoists

1. **DON'T LET MUSCLES** do what a proper size hoist should do.
2. **SMALL HOISTS** aren't expensive. With proper slings and hoist lines, they will help greatly in reducing injuries to workers.
3. **USE THE RIGHT SLING AND HOIST LINE** for the job. Tuffy Slings and Hoist lines are "tailored" to every need, from the smallest block and tackle to giant cranes and other equipment.
4. **DON'T ASSUME** that all slings are right for all kinds of lifting. Your Tuffy distributor will help you select the right ones.



Kinks Are No Hazard with Tuffy Slings

One of the first rules of safety: never use a *wire rope* sling that has been kinked. Not so with Tuffy Slings. Tuffy's patented, 9-part machine-braided fabric is just about impossible to kink. And if it should, it's easy to straighten out the kink, leaving no material damage.

Unique Ferrule Gives the Eye Splice Full Fabric Strength

The steel ferrule is slipped over the tuck-splice of the sling eye and pressed on under tremendous pressure. It gives the eye splice 100% of fabric strength. No abrupt edges or rough projections to injure hands and slow down work. And there's no extra cost for this extra efficiency and safety feature!

Proper Fittings Are An Important Safety Measure

Fittings used on Tuffy Slings are designed for a broad and varied range of needs. Your Tuffy distributor, or Union Wire Rope engineers, will be glad to advise you on the correct fittings for greatest service and safety for any wire rope rigging.

Shown here are Newco Sling Saddles, fittings that are widely used to protect loads and lengthen the life of slings. These saddles are made in two types: Type B and Type T. Both are shown in the illustration. Type T is used at the top of the load; type B at the bottom. They can be changed quickly from one sling to another. They eliminate the strand cutting that occurs around 90° edges and protect the load. Full data on dimensions and weights for Newco Sling Saddles—and the full line of sling fittings—are included in the Tuffy Sling Handbook that's yours for the asking (see below).

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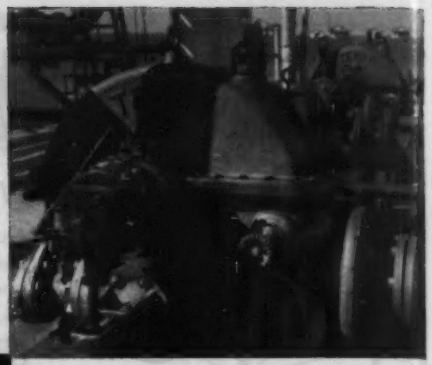

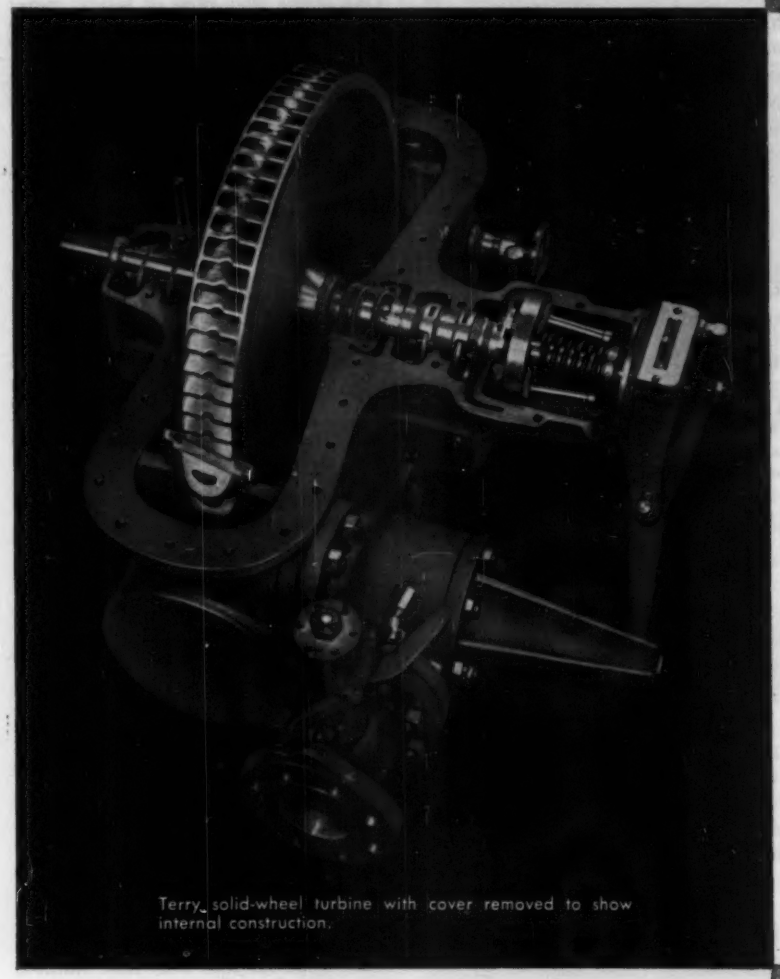

Terry solid-wheel turbine with cover removed to show internal construction.

For mechanical-drive applications, such as these, you will never find the equal of Terry solid-wheel turbines for built-in dependability. They are *designed* for trouble-free operation under the toughest service requirements.

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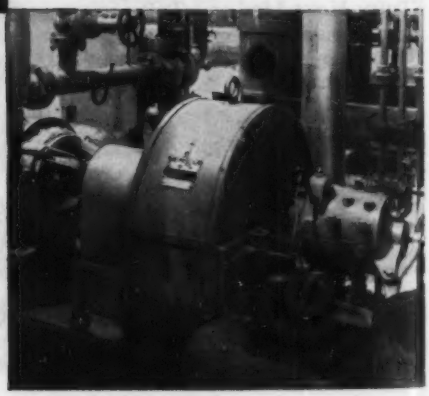

TT-1216

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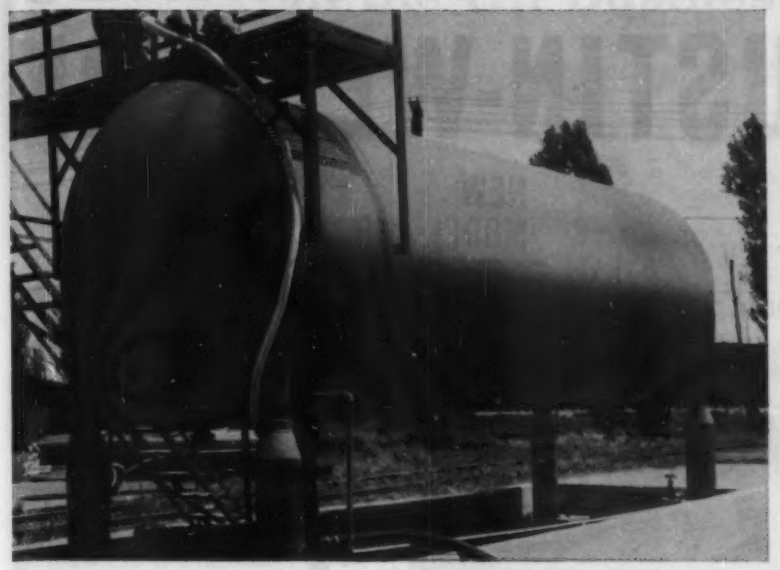

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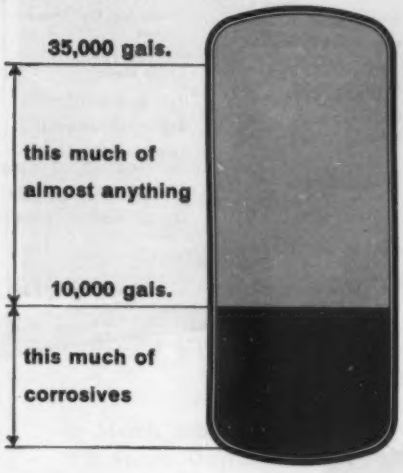

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Available with wide range of accessories for added versatility!

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Because there's no time for Trap Trouble in the Oil Business . . .

by John W. Ritter, Test Engineer
SARCO Company, Inc.

No industry looks with any favor on the prospect of even a partial shutdown. In petroleum refining, the emphasis on continuous, efficient operation is especially strong, because unscheduled shutdowns can be fabulously expensive and often lead to product waste or reprocessing.

Refinery engineers sometimes look upon

Steam Trap manifold for steam tracing, installed in the Cat Reformer at Phillips Kansas City plant.

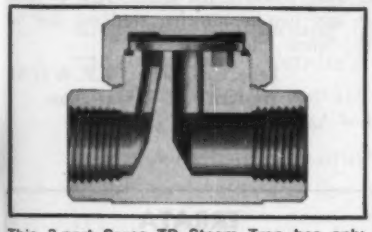
the steam trap as a necessary nuisance, because if the trap does fail, replacement or repairs can cause wasteful downtime.

Refineries use steam traps to do a wide variety of jobs. Applications include drips on transmission lines, tracer lines, tank coils, reboilers, and dozens of other process applications—not to speak of space heating.

Steam traps operating in refineries must fuaction satisfactorily on low pressure or exhaust steam and up through high-pressure, high-temperature ranges, even though outside temperature may vary from subzero to subtropical.

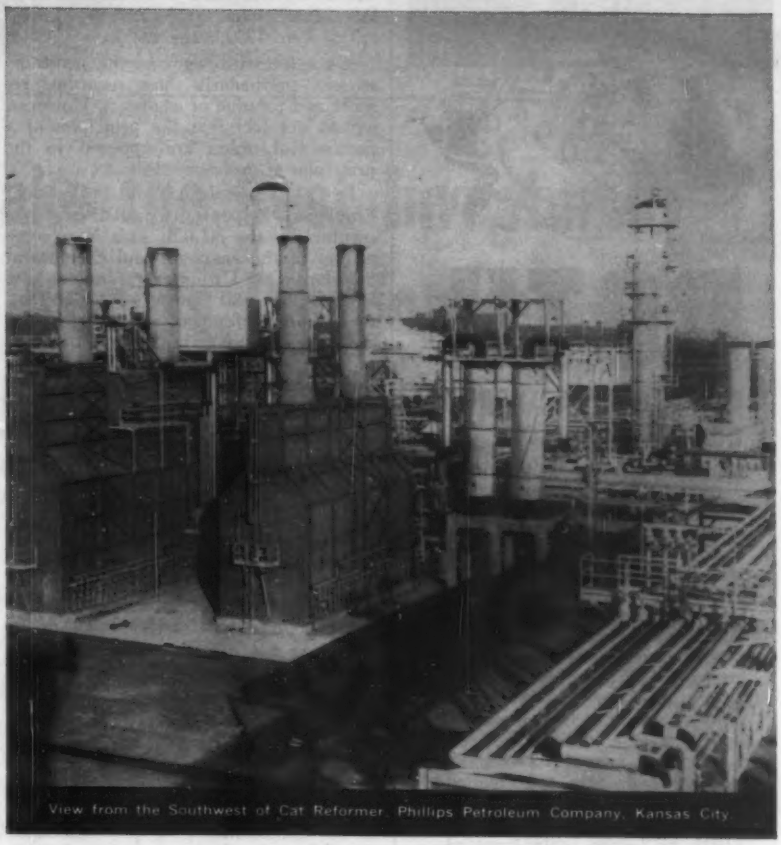
Sarco Thermo-Dynamic Steam Traps have found favor in many types of refinery operations, and the answer lies in the simplicity with which TD's handle condensate and prevent steam loss.

With only one moving part – the stain-



This 3-part Sarco TD Steam Trap has only one moving part – the hardened, polished steel disc.

less steel disc – the TD can be inspected and serviced in 40 seconds. No adjustment is ever needed, and TD Steam Traps are accumulating enviable records of long, trouble-free service in the refinery industry.



View from the Southwest of Cat Reformer, Phillips Petroleum Company, Kansas City

Phillips installs 200 SARCO TD traps on new catalytic reformer

In March, 1954, Phillips Petroleum Company installed its first Sarco TD Steam Trap on a main line drip, on 150 psig steam pressure. Later TD-50's were installed on many different applications. When Phillips built its new Catalytic Reformer Unit (No. 17) some 200 TD Steam Traps were installed. (There are now 1800 TD-50's throughout the refinery.) When the traps are TD's, they need not be a "Necessary Nuisance." Rather, they can be as reliable, efficient and versatile as any other piece of equipment in this field.

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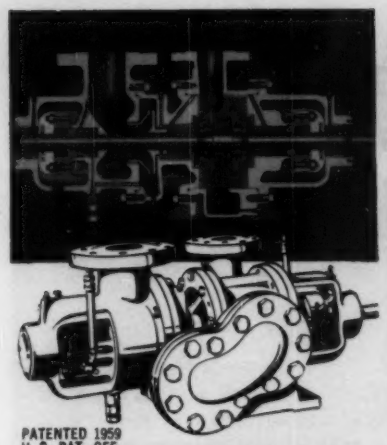

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Head: 150 to 1400 ft.
Differential: 50-600 PSI
Cap: 2 to 100 GPM
Temp: −50° to +250° F.
H.P.: 5-40 BHP
NPSH: as low as ½ ft.

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Stock Castings:
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Complete and comprehensive information on NPSH, seals, and mechanical data plus performance curves on all sizes.

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In Re Professionalism

To The Editor:

We have read with interest the article written by Dr. John J. McKetta, "What Price Professionalism?" (PETROLEUM REFINER, Feb. 1959, page 193.)

We agree with many of the points he stresses, particularly those regarding respect and prestige of engineers. However, we do not feel that the principles of a professional union are opposed to the principles of professionalism.

In 1943 the Research and Professional Employees' Association (REPEA) was certified by the NLRB. This is an association of the engineers and chemists at Standard Oil Company (Indiana) at Whiting. Over 80 percent of the 550 nonsupervisory professional employees voluntarily belong to this association, which provides a two-way channel for communication between the professional employees and the company.

Our association promotes professionalism by encouraging attendance at local and national meetings of technical societies. It endorses programs of educational advancement, it surveys the need for and recommends non-technical assistance to professional employees, it encourages licensing and registration of engineers, it has a standing committee to promote professional advancement.

Professional unions don't have to stifle individual initiative. In fact, by working toward an improved professional climate, they encourage initiative.

We will be glad to send you or Dr. McKetta any further information on REPEA that may be desired. We know that Dr. McKetta has spent much time in the consideration of professionalism and its relationship to unionism, but we feel that he did not know about REPEA and several similar organizations when he wrote his article and will therefore have a number of questions to ask, now that he has learned about us.

J. P. Soderberg,
President REPEA
W. C. Cartmell,
Chairman Professional
Advancement Committee REPEA
Whiting, Ind.

Author's Comment

If REPEA is doing all the things Messrs. Soderberg and Cartmell claim, then indeed they are encouraging professionalism to a marked degree. I have heard of REPEA and similar organizations for a considerable length of time through friends of mine who are presently or have been, members. Through these friends I have received handouts concerning the aims of these organizations. Unless REPEA has printed some new material within the last year I believe I have read most of the material they passed out.

The actual pattern for most unions, even those with lofty purposes in their constitutions, has not approached those claimed by Messrs. Soderberg and Cartmell. The general pattern has been for unions either to do nothing in this line or to concentrate the leadership and initiative in the hands of a few.

PR readers will be interested in a new organization formed to offset the movements of the professional unions. This organization is called V.O.T.E. N.O. (The "Veracious Order To Eliminate Nocent Organizations" which they translate to mean a "truthful order to eliminate harmful organizations.") The activity of this group is financed by voluntary contributions and any funds remaining at the end of their activities will be donated to the United Engineering Center. Additional information may be obtained from the secretary, V.O.T.E. N.O., P. O. Box 1101, Winston-Salem, N. C.

Smog Rule

To The Editor:

We believe the story "Further Restraints on Fuel-Oil Use Proposed for L. A.," page 273, July 1959, is subject to misinterpretation.

1. The present and proposed rule involves fuel oil of more than 0.5 percent sulfur, *not* 0.05 percent sulfur.

2. The year 'round features of Mr. Minckler's proposal refers to the proposed new rule, not the existing one.

3. Thus Mr. Minckler proposed two changes, that fuel oil of more than 0.5 percent sulfur be barred at any time during the year *only* (a) when sulfur dioxide levels reach more than 1 ppm. at any two monitoring stations, and/or (b) when smog is forecast.

Felix Chappellet, V.P. & G.M.
Western Oil & Gas Assn.
Los Angeles

ERRATA

The readers' attention is called to two errors in "Watch Propylene's Steady Growth" by Lewis F. Hatch in the August 1959 issue starting on Page 107:

1) The propylene symbol should have had another hydrogen molecule. 2) Also, on Page 113, Figure 9 should have been the Propylene Tetramer flow diagram from November 1957, page 279, rather than the cumene chart which appeared through error.—*The Editor.*

How to Make the Best Investment in New Process Developments

Whether you are planning an investment in alkylation, isomerization, or the latest developments in any other processes, consider the many questions to be answered satisfactorily if your investment is to be truly sound.

In addition to initial outlay, what will the new unit or units cost *ultimately?* Can they be integrated with existing equipment *economically and quickly?* Will they have the flexibility for *future market needs?* In fact, is it wise to plan on modernizing by *degrees?* Or would you be better off to scrap outmoded facilities and *rebuild completely?*

When the decision is to start from scratch, hundreds of combinations of variables are involved—in choosing location, type and range of crudes, product mix, process lineup, degree of integration, refinery size. Which combination of these and other factors will insure the optimum in efficiency, yields, flexibility for the future, and return on investment?

The M. W. Kellogg Company, which has contributed considerably to and participated in practically all leading refining developments, is in a unique position to advise on *any* individual process or combination of processes. And, by virtue of its complete and coordinated contracting service, can undertake the entire responsibility for process design, engineering, procurement, and construction *within its own organization.*

Of particular benefit to Kellogg clients in the evaluation of new process developments is the addition to Kellogg's engineering facilities of the electronic computer. With this high speed aid, not only can Kellogg engineers devote more time to basic design problems, but the greater number of alternates economically possible with electronic computation assures the optimum process or combination of processes.

—

Kellogg's Process Engineering Division, together with the company's Refinery Plans and Economics Department, welcomes the opportunity to discuss your modernization and expansion programs.

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* A COMPLETE LINE OF STEAM TRAPS, ALL OPERATING ON A PROVEN THERMODYNAMIC PRINCIPLE.

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A PETROLEUM REFINER SPECIAL REPORT

They helped plan this issue. A conference was held to establish the limits and type of material to be included in the 1959 Process Developments Issue. Attending the conference were these industrial experts, left to right: C. E. Parish, Eastern States Petroleum and Chemical Corporation, Houston, Texas; F. G. Turpin, Esso Standard Oil Company, Baton Rouge, Louisiana; H. L. Hoffman, PETROLEUM REFINER Staff; W. H. Litchfield, Gulf Oil Corporation, Port Arthur, Texas; R. A. Woodle, Texaco, Incorporated, Port Arthur, and W. P. Bryan, Shell Oil Company, Deer Park, Texas.*

1959 PROCESS DEVELOPMENTS

Today, product quality dominates the refining picture just as it has in the past. The noticeable difference, however, is the extent which refiners have raised the level of competition.

Octane ratings for motor fuels in the U.S. have gone up about an average of 0.7 unit in the past year. This increase plus the continuing sale of a third-grade high-octane fuel keeps the refiners hard-pressed to maintain competition. Alkylation is supplementing reforming to satisfy this octane demand. In fact the need for alkylation is expected to be so great most refiners are examining alky feedstocks other than butylene. Propylene is the next most popular choice.

Cleanliness and stability are other important product quality measurements. These requirements are causing more and more treating facilities to be installed.

Additives also offer an inexpensive way to better quality. In some cases they postpone the need for more expensive processing equipment, and in other cases they give product quality not achieved by ordinary refining techniques.

In this issue, then, is a group of technical articles which deal with these up-to-date refining situations. The articles cover a number of petroleum products ranging from gasoline and gases to greases and waxes.

And for a bonus, we take a fresh look at extraction. One of the experts in the field, Dr. Scheibel proposed a new way to make calculations for multicomponent liquid extraction. Thus, this issue presents another chapter in the new developments in the petroleum refining industry.

Harold Hoffman

PROCESS AND CONSTRUCTION EDITOR

* The attendance by executives, engineers, superintendents, and other employes of oil and petrochemical companies at these conferences does not constitute an endorsement of Petroleum Refiner over any other one publication. The fact that men of outstanding ability are allowed to attend these planning conferences shows the interest which the oil and petrochemical industry has in sound editoral content planned for the benefit of the industry and those who work in it.

Alkylation Now Goes After Propylene

There is a big shift in alkylation to include propylene in the butylenes feed. Since most new units will be designed with a mixed feed in mind, you will want to keep up with the latest in this development

D. H. Putney and Orlando Webb, Jr.
Stratford Engineering Corp.
Kansas City, Mo.

UNTIL A FEW YEARS ago the alkylation process was used primarily in the alkylation of isobutane with the butenes produced in refinery operations. Subsequently a number of new plants were designed to alkylate isobutane with mixtures of propylene and butenes, with some feeds having very high percentages of propylene. This article will present a summary of the recent experiences of operating companies processing mixed feed stocks, with comments on design factors and trends in the design of propylene alkylation units.

Initially, the alkylation process was used to produce only light aviation grade alkylate for blending with isopentane in making the various military grades of aviation gasoline. The B-B cut from refinery operations was the first stream selected to be alkylated for several reasons:

- The stream contained roughly the right amount of isobutane required by the butenes.
- The C_4 alkylate product gave a high yield of the required performance number aviation alkylate when it was re-run.
- Sulfuric acid catalyst consumption was lowest on the B-B charge stock.

When aviation gasoline purchases began to fall off and motor gasoline octane numbers began rising many refiners shifted over to the use of alkylate as a high octane component in premium motor fuel. Re-run endpoints on light alkylate were increased and in many cases the total alkylate was used without re-running. Alkylate quality was evaluated in terms of clear and leaded Research and Motor octane numbers, instead of lean and rich mixture aviation performance numbers.

As premium motor fuel octane numbers continued to rise, more and more refiners began to use propylene as a part of the alkylation unit feed, rather than as charge to polymerization operations. Several new plants were designed to alkylate all of the propylene and butenes the refinery produced, and some large refineries with already overloaded butene alkylation facilities added complete new units for the alkylation of propylene.

The latest design alkylation unit for mixed feed or straight propylene differs from the earlier butene units in several important respects. These differences involve the following:

- Isobutane make-up requirements
- Fractionation requirement
- Refrigeration load
- Reactor operation

Mixed feed units usually require substantial amounts of outside isobutane since, as mentioned earlier, the isobutane the refinery produces will normally only satisfy the butenes from the cracking operation. Isobutane make-up is normally either (1) purchased isobutane of 90-95 percent purity or (2) field butane of 40-50 percent purity or (3) isomerization plant product of about 90 percent purity. From a study of recent plant operations it may be concluded that the isobutane consumption per volume of propylene in the feed is essentially equal to the theoretical value of 1.28.

Plant material balance checks indicate that no propane is produced in these propylene alkylation systems. This is confirmed by the fact that the depropanizer overhead product is approximately equal to the propane in the feed streams.

There are several differences in fractionation requirements on mixed feed units. Being designed to produce alkylate for motor fuel blending, no re-run towers are normally installed. Total alkylate endpoints usually run considerably less than 400° F, and this enables the refiner to blend the total alkylate directly into premium motor fuel.

High total alkylate vapor pressure is usually permissible in alkylate to be used for motor fuel blending and debutanizer columns are often either eliminated or greatly reduced in size. Vapor side drawoffs from the deisobutanizer are sometimes used in place of a separate debutanizer column.

The main fractionator in a mixed feed plant is often a simple isobutane stripper column unless a large amount of low purity isobutane is also charged to the tower. With a mixed olefin feed and high purity isobutane make-up, an isobutane stripper column will frequently produce recycle of over 85 percent isobutane purity, completely without reflux. This is possible since in such a case there is very little normal butane in the total charge to the unit. If an isobutane stripper column can be used it very substantially reduces both tower investment and operating costs of the unit since a deisobutanizer column may often require a reflux ratio of 3-1 or higher. Depropanizer towers are naturally larger in mixed feed plants.

	BARRELS PER STREAM DAY											
	Olefin Feed 1	DIB O'hd. 2	Eff. Recy. 3	Comp. Feed 4	Total Eff. 5	Net Eff. 6	Trap. Vap. 7	Drum Vap. 8	Refrig. Cond. 9	DP O'hd. 10	iC_4 Make-Up 11	DIB Botts 12
C_3 =	2270	.....	.....	2270	.....	.....	.....	.....	.....	.....	.....	.....
C_3	1891	780	1186	3857	3857	769	3085	1288	4376	1902	11	.....
iC_4	2994	9353	12452	24799	21447	8955	12492	4499	16991	40	450	52
C_4 =	402	.....	.....	402	.....	.....	.....	.....	.....	.....	.....	.....
nC_4	614	871	1370	2855	2855	1485	1370	321	1691	.....	676	1290
iC_5	42	.....	86	128	365	279	86	7	93	.....	3	282
C_5+	.....	.....	23	22	4526	4504	22	.....	22	.....	.....	4504
Total	8213	11004	15116	34333	33050	15992	17058	6115	23173	1942	1140	6128

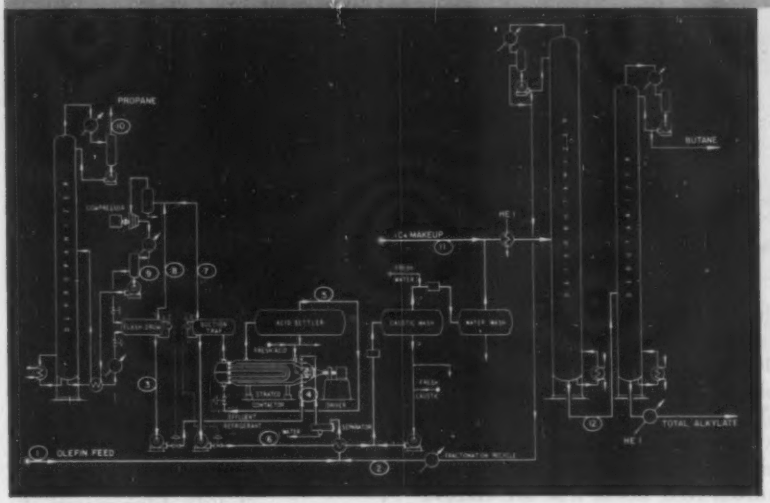

FIGURE 1—Even though the olefin feed consists mostly of propane and propylene, the concentration of propane throughout the unit is kept quite low.

A flow diagram of an effluent refrigerated alkylation unit and an over-all material balance for a high propylene feed stock are shown in Figure 1. The outside isobutane make-up stream is assumed to be of low purity and, therefore, a conventional deisobutanizer and debutanizer are shown. The degree of debutanization would naturally be varied as required to satisfy the alkylate vapor pressure specifications. Even with the low purity isobutane make-up assumption, note that recycle requirements for the propylene feed are not excessive in the effluent refrigerated system.

Note also that even though the olefin feed consists mostly of propane and propylene the concentration of propane throughout the entire unit is kept quite low in the effluent refrigerated design. In the hydrocarbon effluent from the reaction zone the propane concentration is only 11.7 percent. Propane is concencentrated by flashing the effluent refrigerant and in this example the propane concentration in the depropanizer feed is 18.9 percent.

Refrigeration requirements are somewhat greater in mixed feed units than they are in butene plants since the heat of reaction is higher. The heat of reaction for propylene is approximately 840 Btu per pound of propylene reacted, compared to 615 Btu per pound for butenes. Compression ratios vary only slightly since isobutane is the principal component of the refrigerant vapor with either feed stock.

Insofar as the contactors are concerned there are several major differences in selection and operation on mixed feed stocks. The most important consideration is the olefin space velocity in the acid catalyst. The true space velocity of an alkylation reactor, by definition, is computed by dividing the gallons per hour of olifin in the reactor feed by the instantaneous inventory of acid resident in that portion of the reactor occupied by emulsion in which acid is the continuous phase.

In this particular system velocities are maintained sufficiently high in the contactor to prevent any acid separation or emulsion inversion, and therefore, the entire acid volume of the contactor may be considered equally effective with respect to space velocity. Since no acid gradient exists in the reaction zone the space velocity in this system is computed by simply dividing the gallons per hour of olefin in the contactor feed by the product of the contactor volume in gallons and the acid content of the emulsion in volume percent. Lower space velocities result in the production of higher quality alkylate with reduced acid consumption.

On mixed feed units contactors of larger operating volume are used. The contactors are operated with a maximum amount of acid in the reacting emulsion consistent with available power input and acid settler limitations. Note that unlike some reactor systems the acid content of the emulsion can be readily controlled in this system by simply regulating the flow of recycle acid from the acid settler. Mixing horsepower is preferably maintained at a maximum by operating the unit at maximum speed.

In the best mixed feed operations the acid recycle rate is set so high that an appreciable depth of "fluff," i.e., a stable emulsion layer, exists in the settler. An emulsion which takes 8-10 minutes or longer to show the first small increment of hydrocarbon separation is necessary for best results. Such an emulsion has acid as the continuous phase with an extremely finely dispersed hydrocarbon phase. This type of emulsion is much more difficult to separate than an emulsion containing less acid and into which less mixing energy has been expended. In the acid settler there may be a zone of emulsion, often several feet in depth, between the hydrocarbon and acid phases. The emulsion layer can be observed in settlers equipped with a number of individual gage glasses connected directly into the settler shell. Each of the gage glasses in the emulsion zone will show an acid layer.

By proper adjustment of acid re-

TABLE 1—Alkylation With Mixed Feed

OPERATION	A	B	C	D	E
OPERATING PERIOD	Month Average	Month Average	Typical	Test Run [1]	Typical
Propylene, Percent	97	79	55	80	45
Butenes, Percent	3	21	45	20	55
Olefin Space Velocity	0.175	0.160	0.300	0.128	0.210
iC_4/olefin in feed	10.0	11.7	9.5	10.9	11.0
iC_4 percent in effluent	66	(68)	72	74	72
Contactor Temperature, °F	47	45	43	43	49
Acid in Emulsion, Percent	66	65	60	65	50
Acid Make-Up, #/gal. alkylate	1.10	0.66	0.70	... [2]	0.64
Discard Acid Strength, Percent H_2SO_4	90.0	90.0	91.5	90.0	90.0
Total Alkylate Properties Distillation					
IBP	134	133	112	.....	90
10 Percent	172	172	164	.....	135
50 Percent	196	201	212	.....	213
90 Percent	278	250	264	256	260
EP	376	363	396	367	370
RVP	(4.5)	4.5	5.8	9.5	10.5
F-1 Octane Clear	88.6	91.5	93.4	94.0	95.0
F-1 Octane (+3cc TEL)	101.0	102.6	104.6	104.5	107.0

Parentheses denote estimated values.
[1] Semi-Commercial Run.
[2] Run of insufficient length to determine acid consumption.

cycle rate, mixing horsepower input and acid inventory it is possible to operate a settler with as many as four out of a total of seven gage glasses showing both hydrocarbon and acid, without carryover of acid in the settler overhead. Without this type of emulsion high propylene content mixed feed stocks will produce a poor alkylate and require a very high acid make-up rate.

Using the "tight" high acid content emulsion technique excellent results are obtained in alkylating isobutane with propylene. Table 1 illustrates examples of results from operations with varying percentages of propylene in the total olefin charge.

The excellent boiling range of the total mixed alkylate product and the very low acid make-up requirements are of particular interest. Results vary somewhat due primarily to the fact that the runs differ widely in space velocity. Even at the higher space velocity conditions the boiling range and acid consumption that have been experienced on the high propylene stocks are considerably better than previously considered possible. Until recently acid consumption on these stocks has been considered prohibitive by many refiners and the small amount of experience that has been available has indicated that total alkylate 90 percent point and endpoints would be very high and rerunning was absolutely essential. Acid consumption in the order of 2 pounds per gallon or higher has been frequently reported, and total alkylate endpoints of 550° F were obtained. The examples shown in Table 1, however, clearly illustrate that a properly designed system operated under the right conditions can produce results from mixed feed stocks that are comparable with many plants operating on a B-B charge.

Design trends. Existing refineries without alkylation and new refinery installations will in most cases be designed to alkylate all available propylene and butenes from cracking operations. Where field or purchased isobutane is not available at reasonable cost isomerization of normal butane will be included. Many of the larger existing plants with butene alkylation facilities will add new propylene alkylation units consistent with the above isobutane availability limitations. The contactor sections of the future mixed feed units will be designed for lower space velocities and for higher mixing horsepower inputs. The acid settlers on these units will be designed with improved facilities for observing the emulsion composition at various levels.

The recent operating and engineering advances described herein have greatly improved the economics of alkylating mixed feed stocks. This should result in more alkylation capacity being installed in the near future and the conversion of larger quantities of propylene into high octane motor gasoline.

The Sulfuric Acid Alklation Process, the effluent refrigeration system and certain techniques described here are the subjects of pending and issued patents owned by a number of companies. ##

About the Authors

Putney

Webb

D. H. Putney is president of Stratford Enginering Corp., Kansas City, Mo. He joined Stratford in 1936 as chief engineer, became technical director in 1945 and vice president in 1950. Putney received an engineering degree from the University of Kansas in 1922, and was with Sinclair Refining Co.'s Engineering and Construction Department from 1923-25. He then joined Cross Engineering Co., which later became part of The M. W. Kellogg Co., and remained until 1931 doing process design work. From 1931-36, he was with American Locomotive Co.'s Alco Products Division, New York, serving for two years as chief mechanical engineer. Putney's industry experience encompasses 37 years.

Orlando Webb, Jr., is a vice president of Stratford Engineering Corp., Kansas City, Mo., where he is in charge of process design and development, and sales of specialized equipment. With Stratford for about nine years, he has been a process engineer serving in a staff capacity. Webb received a B.S. degree in petroleum engineering from the University of Kansas in 1947. He then worked for Standard Oil Co. (Indiana) for two years at Sugar Creek, Mo., refinery as enginering field representative on new construction and performance tests of new cracking, vapor recovery and poly units. He was also with The Dow Chemical Co. in process design of its Freeport, Texas, plant expansion.

Wondering how to evaluate the effects of a catalyst switch in your fluid cat cracker? Here's how one refiner did it in a commercial size unit

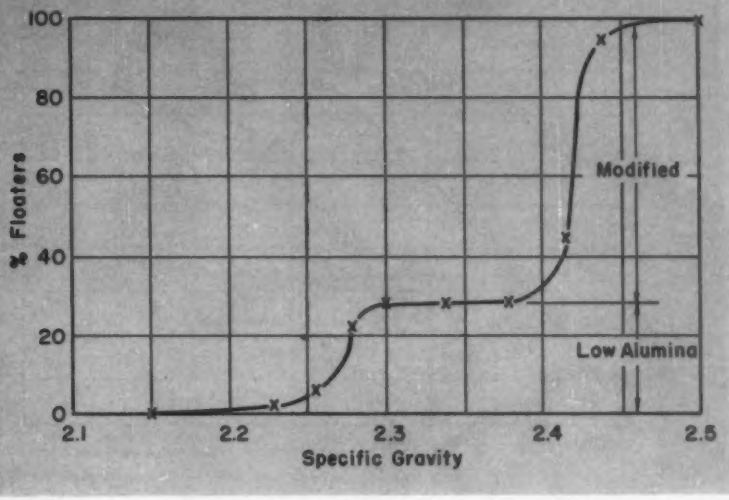

FIGURE 1—The density of the new catalyst was sufficiently different from that of the catalyst then in use so that separation could be achieved easily.

Considering a Catalyst Change Soon?

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PROPER COMMERCIAL evaluation of a new fluid catalyst is much more difficult to achieve than is a fixed or moving bed catalyst. Because of the inherent nature of the fluid system, it is not feasible to replace immediately one catalyst with another. The catalyst replacement must be done gradually.

Since changes in the properties of the equilibrium catalyst occur over a long period of time, it may be some time before undesirable properties begin to appear. Therefore, refiners are reluctant to evaluate new catalysts. It is desirable then to have a technique which will permit following the more important properties of the new equilibrium catalyst long before it reached relatively large proportions.

A recent publication[1] described a method by which fresh synthetic catalyst, added to equilibrium catalyst, could be followed in some detail. This method, employing a variable density sedimenting fluid, permitted separation of catalysts differing in skeletal density, pore volume, and pore diameter. Here is how the monitoring technique permitted a new modified synthetic catalyst to be evaluated in a commercial unit of Aurora Gasoline Company, Detroit.

TABLE 1—Typical Analysis for Separated Equilibrium Catalyst

CATALYST	Equil.	Modified Portion	Low Alumina Portion
Percent of total.....	100	77	23
Percent Al_2O_3.....	28.8	33.1	13.3
Wt. Rel. Act. U.O.P..	35	36	30
Vol. Rel. Act. U.O.P..	46	46	45
App. Bulk Den..	0.66	0.62	0.74
Surface area M^2/GM	115	113	120
Pore vol. (N_2) CC/GM	0.41	0.44	0.33
Pore vol. (H_2O) CC/GM.....	0.46	0.51	0.34
Pore Dia. (N_2) Å....	142	156	110
Pore dia. (H_2O) Å...	160	180	121

Laboratory investigation of the skeletal density of the modified synthetic showed that its equilibrium skeletal density was sufficiently different from that of the low alumina catalyst then in use so that separation could easily be achieved. Using a solution of tetrabromoethane in tetrachloroethane, it was found that low alumina floated (Floaters) and modified synthetic sank (Sinkers), when the density was maintained between 2.32 and 2.38.

The procedure used in separation is to burn the carbon off the catalyst, following which the sample is cooled in a desiccator. The sample

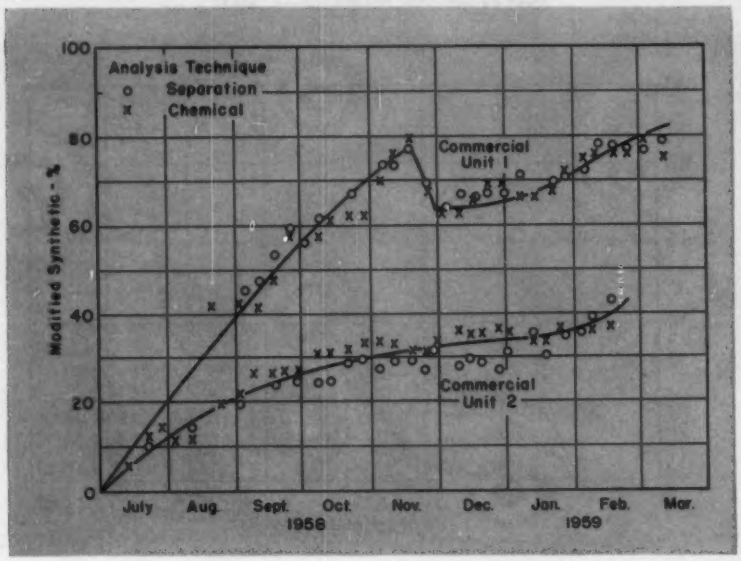

FIGURE 2—The separation technique gave results which agreed very well with those from chemical analyses. By the separation technique then it is possible to follow many properties of the catalyst.

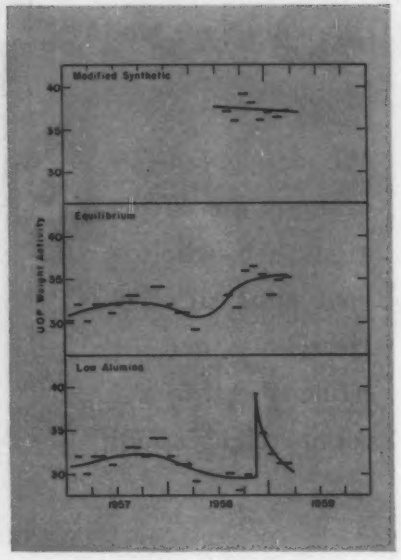

FIGURE 3—Equilibrium activity gradually rose although catalyst addition rates were maintained at about the same level.

is then added to a solution of tetrabromoethane in tetrachloroethane adjusted to the desired density. The minimum volume ratio of solution to catalyst is 2. After shaking and allowing to stand for a short period of time, the slurry is placed in a centrifuge and separation achieved. The separated portions are filtered, thoroughly washed with methanol to remove sedimenting fluid, dried at 300° F, and calcined further at 900° F for two hours prior to submitting for evaluation.

It was also observed that low alumina, high alumina, modified synthetic, bentonite and halloysite type catalysts, all could be separated, one from another by careful control of sedimenting fluid specific gravity. A typical separation of modified synthetic and low alumina from the Aurora equilibrium catalyst is shown in Figure 1. Chemical analyses of the separated portions, shown in Table 1, confirm the cleanness of separation. The agreement in the modified synthetic content of equilibrium catalyst is shown in Figure 2 for two commercial units as independently determined by chemical and separation analysis.

By means of this technique then, it was possible to follow many properties of the catalyst.

The new catalyst is a chemical combination of silica, alumina, and a specially selected and treated clay. The chemical and physical properties of the modified synthetic catalyst are compared with typical synthetic low and high alumina catalysts in Table 2. Specific differences between this catalyst and previous synthetic catalysts are the increased alumina content, the lower surface area and the slightly lower pore volume. The average pore diameter of the new catalyst was found to be considerably larger than that normally observed for catalysts of this type.

The virgin activity, and activities

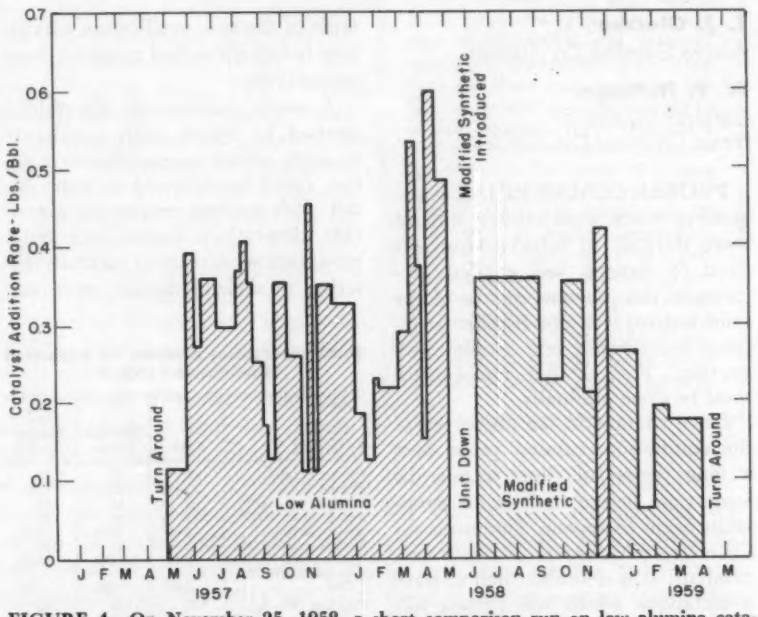
Catalyst Addition Rate - Lbs./Bbl.
Turn Around
Low Alumina
Modified Synthetic Introduced
Unit Down
Modified Synthetic
Turn Around
J F M A M J J A S O N J F M A M J J A S O N J F M A M
1957
1958
1959

FIGURE 4—On November 25, 1958, a short comparison run on low alumina catalyst was initiated.

observed after thermal and steam treatment are shown in Table 3. At the higher severity levels of steam treatment it was observed that the catalyst activity closely approached that of both high and low alumina.

Extensive product distribution studies carried out in the laboratory, further confirmed that the catalyst was essentially equivalent to synthetic in cracking characteristics. Table 4 summarizes these results. Table 5 summarizes the properties of the Mid-Continent gas oil employed in these studies. Similar studies on many other widely varying feed stocks further confirmed equivalency.

CATALYST EVALUATION

Early in July 1958, addition of the new modified synthetic catalyst began in two commercial units, one of which was the Aurora Gasoline Company. Here are some of the changes which were identified by the monitoring technique during the catalyst switch:

Activity stability was of primary concern. Preliminary studies on equilibrium catalyst using the above mentioned separation technique confirmed that catalyst properties were unaffected by this process. Therefore the catalyst was separated into low alumina and modified synthetic portions, and the individual activities and physical properties evaluated.

The activity of both portions of the catalyst as well as the equilibrium activity as a function of time is shown in Figure 3. Addition rates are shown in Figure 4. Averages for six months are given in Table 6. Although catalyst addition rates were maintained at about the same level as previously employed, equilibrium activity gradually rose to a 35 UOP activity, and modified synthetic equilibrium activity continued above the activity line.

On November 25, 1958, a short comparison run on low alumina was initiated to further establish the relative behavior of the two catalysts. On that date 15 tons of low alumina were added to the unit. Over a period of approximately 12 days, further low alumina was added at the rate of 2.2 tons per day. Immediately the activity of the synthetic portion rose to that of equilibrium activity, and then returned to lower values following discontinuation of addition. No changes in unit operations or product quality or distribution were observed during this period. The activity of the modified synthetic portion also dropped off slightly and then began to climb again as addition was resumed in December. During this latter period and the months of January and February, modified synthetic catalyst addition rates were reduced in order to increase heating oil production.

Examination of catalyst addition rates over equivalent periods of time indicated that a higher UOP activity, higher by several units, could be obtained for equivalent or slightly lower addition rates, at a savings of $90 per ton.

A similar confirmation study of equilibrium catalyst from Commercial Unit II showed the same general trends, although the interpretation was not complicated by the low alumina addition made in the Aurora Gasoline Operation (Commercial Unit I).

Surface area of the low alumina portion declined in a regular manner until fresh addition was renewed in November. During this period, modified synthetic surface area declined in a normal fashion, and again lined out following resumption of addition. See Figure 5. It is interesting to note the ease with which the abrupt rise and decline of surface area of the low alumina portion was followed during this period. Separation of old and new low alumina by differences in pore volume can also be achieved at this point, and a more detailed picture of surface area decline obtained on the fresh portion.

Apparent bulk density change observed over the nine months is shown in Figure 6. These results confirmed that the new catalyst had a particularly stable bulk density which increased only very slowly. The bulk density of low alumina dropped very rapidly during the period of addition, and then returned to a steady state value within one month. During this period of low alumina addition there was very lit-

TABLE 2—Chemical and Physical Properties of Silica-Alumina Catalysts

TYPE	Modified	High Alumina	Low Alumina
Percent AL_2O_3	33	25	13
Surface area, M^2/GM.	255	460	500
Pore vol. (N_2), CC/GM	0.62	0.80	0.77
Pore vol. (H_2O), CC/GM	0.71	0.80	0.77
Pore dia. (N_2), Å	97	69	62
Pore dia. (H_2O), Å	111	69	62

TABLE 3—Cracking Activity (UOP Method)

TYPE	Modified	High Alumina	Low Alumina
3 Hrs 1112°F			
Wt. rel. act.	60	105	110
Vol. rel. act.	61	93	101
App. bulk den.	0.49	0.44	0.46
6 Hrs. 1630°F			
Wt. rel. act.	44	62	57
Vol. rel. act.	53	80	76
App. bulk den.	0.60	0.65	0.67
6 Hrs. 1200°F—60 psig Steam			
Wt. rel. act.	41	46	36
Vol. rel. act.	41	44	36
App. bulk den.	0.50	0.48	0.50

TABLE 4—Product Distribution
(55% Conversion, 60 PSIG Steam, 6 Hours @ 1200° F)

TYPE	Modified	High Alumina	Low Alumina
Yield, wt. percent			
H_2	0.1	0.1	0.1
C_1	0.8	0.8	1.0
C_2	1.2	1.1	1.3
C_3	2.3	2.4	2.4
$C_3^=$	4.1	3.7	3.6
i-C_4	5.7	6.0	5.9
n-C_4	0.9	0.9	0.9
T-$C_3^=$	3.4	3.4	3.2
C_5-400°F	32.7	32.6	32.8
Coke	3.9	4.0	3.8
H_2, SCF/BBL	49	39	30

TABLE 5—Mid-Continent Gas Oil

API Gravity 60°F	32.3
Specific Gravity 60°F	0.864
Engler Distillation (100 ml.)	
IBP, °F	538
5 percent over	568
10	579
50	646
90	745
95	761
Sulfur, wt. percent	0.35

TABLE 6—Catalyst Daily Replacement

	Catalyst Type	Percent of Inventory	#/BBL	Avg. Equil. Act.
January-June 1957	Low Alumina	0.78	0.185	31
July-December 1957	Low Alumina	1.15	0.274	33
January-June 1958	Low Alumina	1.18	0.305	31
July-December 1958	Modified	1.40	0.347	34.5
January-April 1959	Modified	0.60	0.144	34.5

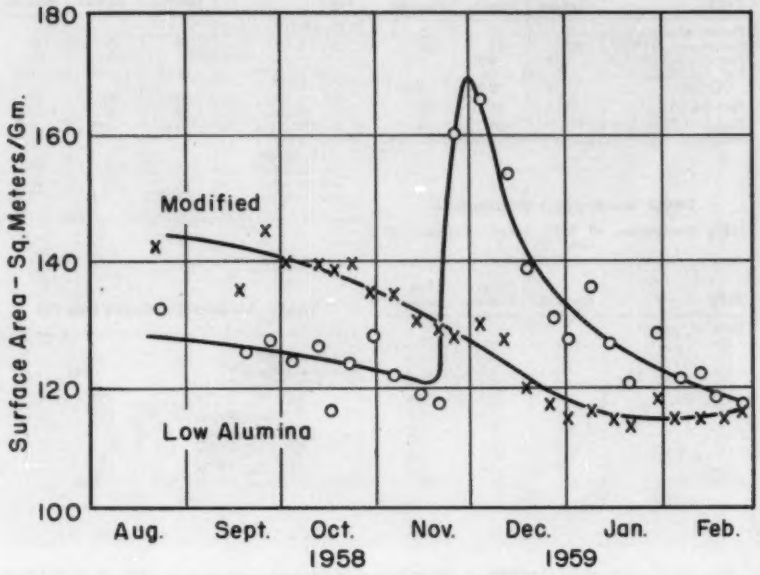

FIGURE 5—The separation technique made it easy to follow the variations of each catalyst within the catalyst mixture.

tle change in modified synthetic bulk density, or pore volume.

Pore diameter of both portions as a function of time is plotted in Figure 7. Because of the larger, and dual pore structure of modified synthetic, pore volume as normally measured by nitrogen condensation was found to be approximately 0.06 to 0.09 cc/gm lower than that observed by water titration, whereas the pore volume of low alumina was essentially equivalent for both methods. Average pore diameter, based on pore volume and surface area considerations, is therefore somewhat larger when pore volume by water titration is employed. By either method, the equilibrium pore diameter of the new catalyst is considerably larger than that of equilibrium low alumina. Again low alumina pore diameter fell rapidly and returned during the period of addition.

Product distribution was evaluated in a laboratory unit. This unit is employed as a research tool for screening new catalysts and for measuring and comparing changes in product distribution characteristics of equilibrium catalysts. Results are only directionally applicable to commercial operations. Absolute values to be expected in commercial operations are obviously not obtained. All product distribution studies are normally made on the Mid-Continent gas oil, although occasionally catalyst comparisons are made on customer feed stocks when appreciable differences in feed stock characteristics are involved.

The results of this evaluation are summarized in Table 7. Equilibrium catalysts containing varying amounts of modified synthetic showed a slightly higher gasoline and iso-butane yield and a lower hydrogen and coke value than for equilibrium low alumina. Within experimental error, octane number was essentially constant. Very little difference was noted between catalysts containing 41 and 77 percent modified synthetic.

In order to further compare the cracking characteristics of both portions, a large quantity of equilibrium catalyst was separated into low alumina and modified synthetic portions, and separately evaluated for product distribution. Equilibrium catalyst from Aurora contained an appreciable amount of magnetically removable iron. This material, while mainly microspherical in character was found to consist of a mixture of iron oxide, plus high concentrations of iron oxide on low alumina. This material was also shown to have an appreciable surface area. In the separation procedure, because of its higher skeletal density, this material tended to accumulate in the modified synthetic portions. Since this material was shown to influence hydrogen and coke make, (compare Tables 7 and 8) it was magnetically removed from equilibrium catalyst prior to separation in order that a true comparison of the two portions might be obtained.

The results of this evaluation are shown in Table 8. It will be noted that product distribution varies slightly from that reported in Table 7 and is presumably due to removal of the magnetic iron. Again, product distributions for equilibrium catalyst and separated portions are essentially equivalent, although there

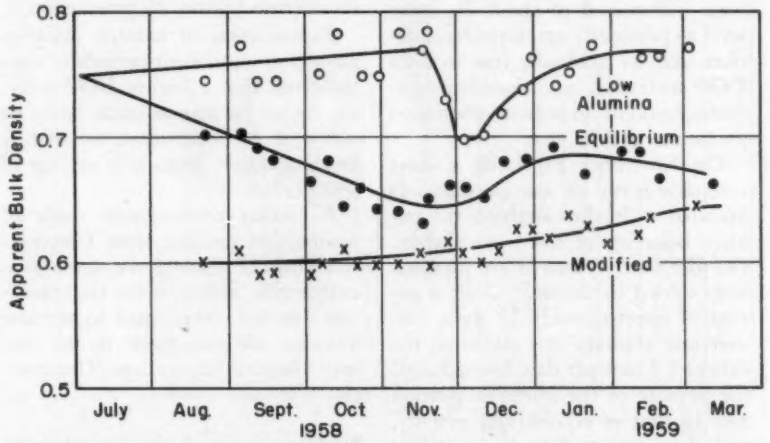

FIGURE 6—The new catalyst had a stable bulk density which increased only very slowly.

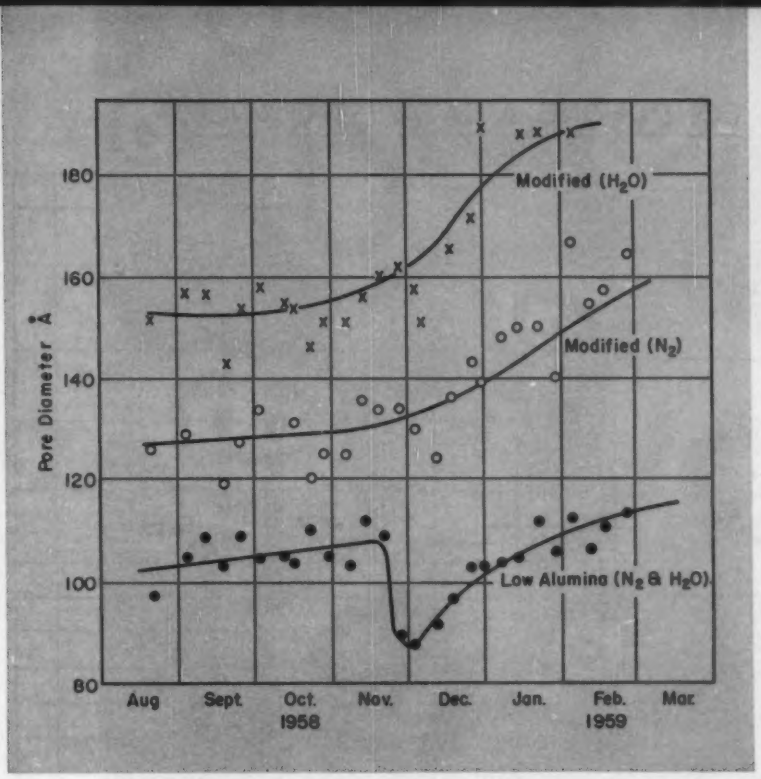

FIGURE 7—By either nitrogen condensation or water titration, the pore diameter of the new catalyst is larger than low alumina catalyst.

does appear to be a slightly lower coke and hydrogen make and higher iso-butane and butylene yield for the modified synthetic.

COMMERCIAL OPERATIONS

By way of introduction, a brief review of Aurora's operations should be made. Aurora processes primarily Michigan and Wyoming crudes. Sweet and sour, virgin and hydrodesulfurized gas oils as well as coker gas oils are cracked alternately and in varying ratios in a blocked out operation. For this reason product distributions and quality fluctuate to some extent, depending on the nature of the particular operation. Light ends from the fluid unit are combined with other light ends from coker, visbreaking and reformer operations. Because of this method of handling light ends, it has not been possible to precisely split out yields from the individual operations. Because of this factor, and the continuously changing character of the feed stock, it is difficult to obtain absolute comparisons of the two catalysts in terms of gasoline, butane, butylene, propylene, hydrogen and coke yield. Direct comparison of octane numbers is also difficult due to swings in volatility and sulfur content resulting from changes in feed stock and processing. However, since essentially the same types of feed stocks have been processed in much the same manner over a period of two years, both before and after introduction of modified synthetic, reasonable comparisons can be made. As indicated previously, catalyst addition rates were essentially equivalent for both periods. Very little operational or product quality information is available for the period May 1 to Sept. 1, 1958, when Aurora was on strike.

TABLE 7—Equilibrium Catalyst
(55% Conversion)

Modified Catalyst, Wt. Percent	0	41	69	77
Yield, Wt. percent				
H_2	0.5	0.3	0.3	0.3
C_1	1.2	1.1	1.1	1.1
C_2	1.2	1.1	1.2	1.1
C_3	2.4	2.2	2.1	2.3
C_3	3.4	3.5	3.5	3.6
i-C_4	3.7	4.7	4.5	4.5
n-C_4	1.1	1.1	1.1	1.0
T-C_4	3.9	4.1	4.1	4.0
C_5-400°F	31.5	31.9	32.0	32.1
Coke	6.1	5.0	5.1	5.1
H_2, SCF/BBL	287	173	192	185
Research O. N. + 3CC TEL	99.4	99.7	99.4	99.3

Octane Number. Due to the above factors, it is difficult to state categorically that an increase in octane number resulted, following addition of modified synthetic. Certainly, taking the opposite viewpoint, there was essentially no evidence that octane numbers dropped below those previously obtained. See Figure 8.

Gasoline Yield. Due to continuously changing feed stocks and requirements for gasoline and heating oil, it is difficult to make absolute comparisons of yields. However, the yield of gasoline and heating oil, as well as poly gasoline and butane, based on previous experience remained essentially unchanged.

Coke make dropped after introduction of modified synthetic in spite of the fact that iron, nickel and vanadium were at high levels during the latter part of last year and this Spring. See Figure 9.

H_2 production dropped considerably following introduction of modified synthetic. Again this occurred during a period when metals were gradually increasing in concentration.

TABLE 8—Aurora Equilibrium Catalyst Selectivity Results—Magnetic Iron Removed
(77% Modified Synthetic)

Catalyst Sample	Equilibrium Mixture			Equilibrium Modified Synthetic "Sinkers"			Equilibrium Low Alumina "Floaters"		
Conversion, Wt. %	45	55	65	45	55	65	45	55	65
Yield, Wt. %									
Hydrogen	0.2	0.2	0.3	0.2	0.2	0.3	0.3	0.3	0.4
Methane	0.8	1.1	1.4	0.7	1.0	1.4	0.8	1.0	1.4
Ethane & Ethylene	1.1	1.2	1.6	0.9	1.1	1.5	1.0	1.2	1.7
Propane	1.5	2.3	3.3	1.4	2.2	3.2	1.4	2.4	3.4
Propylene	3.5	4.1	4.5	3.5	4.1	4.5	3.4	3.9	4.2
Iso-Butane	3.3	4.5	5.4	3.5	4.5	5.5	3.0	4.4	5.6
n-Butane	0.6	1.1	2.1	0.6	1.1	1.9	0.7	1.2	2.0
Butenes	3.6	4.6	5.4	4.0	5.0	5.6	3.9	4.7	5.2
C_5-400°F	27.8	31.5	34.2	27.7	31.6	34.3	27.9	31.3	33.9
Coke	2.6	4.4	6.8	2.5	4.2	6.8	2.6	4.6	7.2
H_2S.C.F./Bbl.	117	149	188	114	144	178	156	191	230
C_5 — 400° F, Vol. %	32.9	37.3	40.5	32.7	37.3	40.5	33.0	37.0	40.1
Gasoline/Coke	10.7	7.2	5.0	11.1	7.5	5.1	10.7	6.8	4.7
RON + 3cc TEL	.....	99.7	.....	.....	99.8	.....	.....	99.7	.....

Note: Run Conditions—Mid-Continent Gas Oil, 10 cc/min. feed rate, 900°F, 15 min. run time, fluidized fixed bed. C/O = 4-7.
All values rounded off to nearest tenth.

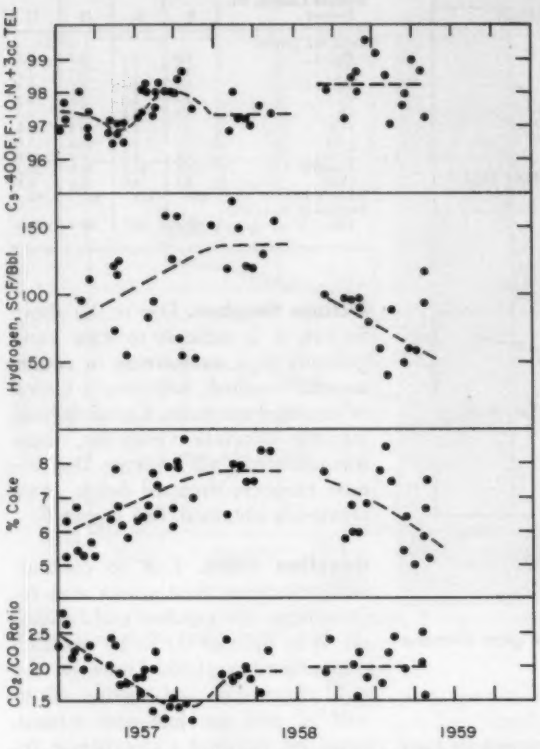

FIGURE 8—Product distribution and quality fluctuate because of variations in the stocks being cracked.

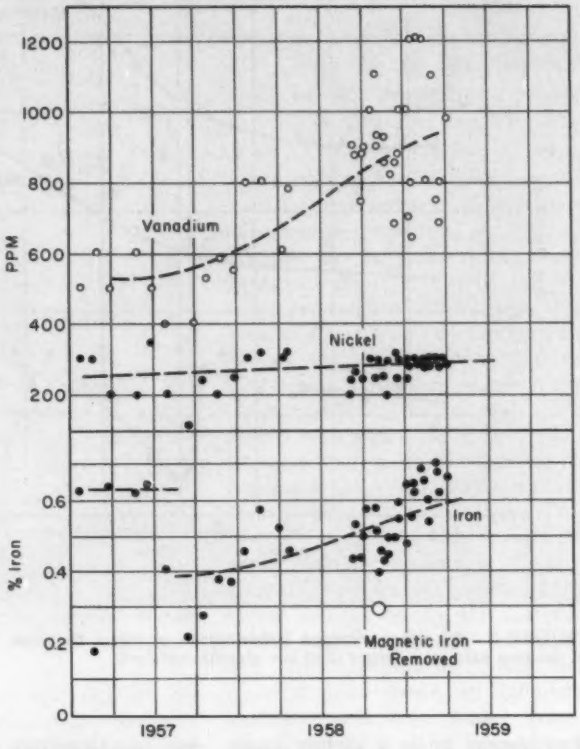

FIGURE 9—Vanadium, nickel and iron were at high levels during the latter part of last year and this spring.

CO_2/CO ratios, always high on this unit, and probably at least partially due to the high metals level, did not change appreciably following modified synthetic addition. No changes in regeneration characteristics have been observed to date.

Other Observations. With regard to the gradually decreasing bulk density of the catalyst, no fluidization or operating difficulties were experienced. In fact, it is generally felt that overall operations have been smoother since going on this catalyst. Operating conditions remained essentially unchanged. During a turnaround in April of this year, the unit was thoroughly inspected for signs of increased erosion. No unusual erosion was observed.

In summary, based on essentially equivalent addition rates, Aurora has found modified synthetic to compare favorably with low alumina. At the present rate of addition of approximately 2 tons a day, catalyst costs are reduced approximately $180 per day. At this writing nine units are operating on this particular modified synthetic, and six of these units are being followed closely by this technique. No adverse observations have been reported for any of the units.

ACKNOWLEDGMENT

The authors wish to express their appreciation to Aurora Gasoline Company and Nalco Chemical Company for permission to publish these results, to members of both staffs who made this evaluation possible, and to Peter Blasco, formerly of Aurora, and presently of Vickers Petroleum Company who arranged for this cooperative study.

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FIGURE 1—When naphtha reforming produces insufficient hydrogen by-product, a separate hydrogen plant can be constructed. In this view of such a hydrogen plant, the rectangular structure at right is the furnace which converts hydrocarbon gases to hydrogen. Columns at left are reactivator and absorber of the carbon dioxide removing facilities.

Need Hydrogen? Examine This Process

This process furnishes the hydrogen needed for treating American Gilsonite's unique feedstock. Look it over. It can also be the answer to other refiners who need more hydrogen

Norman C. Updegraff
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THE CURRENT TREND in hydrogen treating of refinery streams for feedstock preparation and product up-grading increases the need for hydrogen. In some cases this need is greater than can be supplied by the convention gasoline reformer off-gases. The refiner then turns to other means of hydrogen production.

The unique feedstock of the American Gilsonite Company caused them to be one of the two first U.S. refineries to install separate hydrogen-producing facilities. Their plant near Grand Junction, Colo., is said to be the first privately financed commercial operation to produce high-octane gasoline from a solid hydrocarbon, Gilsonite ore. During catalytic reforming of this unusual material insufficient hydrogen by-product is generated and additional hydrogen is produced on the site to augment the reformer supply.

The hydrogen required by American Gilsonite is produced by steam-hydrocarbon process in a plant engineered by Girdler Construction Division of Chemetron Corporation and erected by H. K. Ferguson Company. It has a capacity of approximately 600,000 cubic feet per day of 92 percent hydrogen. The normal feedstock is a refinery stream consisting largely of propane and butane. The plant is also designed to use various alternate feedstocks for startup. It has been in operation since May, 1957.

The Girdler hydrogen plant—a type more or less standard in the chemical and edible oil industries,

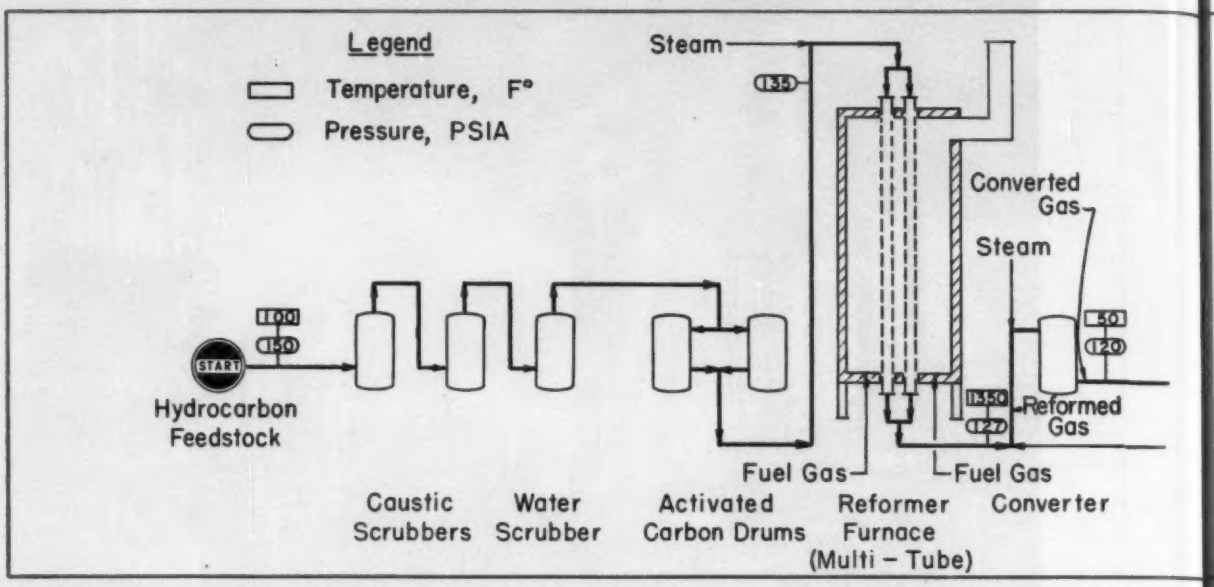


FIGURE 2—The hydrogen plant is typical of the more recent trend toward operating the steam-hydrocarbon process at elevated

but still new to the petroleum industry—is typical of the more recent trend toward operating the steam-hydrocarbon process at elevated pressure to take advantage of the available pressure of the feedstock and thus save in subsequent hydrogen compression costs.

How Hydrogen Is Produced. A schematic flowsheet of the hydrogen plant is shown in Figure 1. The normal feedstock for the process consists of a stream available from the refinery at 150 psig which has the average composition shown in Table 1.

TABLE 1—Feed for Hydrogen Production

Components	mole %
H_2	10
CH_4	2
C_2H_6	13
C_3H_8	44
iC_4H_{10}	12
nC_4H_{10}	15
iC_5H_{12}	1
nC_5H_{12}	1
C_6	Trace
H_2S	2
NH_3	(5 ppm)
COS	(3 ppm)

This gas contains sulfur compounds that would temporarily deactivate the nickel catalyst used in the hydrogen plant. Therefore, provisions were installed to remove them. Two stages of sulfur removal are used. The first consists of two drums in series containing a caustic solution to remove the hydrogen sulfide present. Periodically fresh caustic solution is charged to the caustic scrubbers and the spent caustic discarded. The caustic wash is followed by a water scrubber to remove traces of caustic that might be carried over with the gas. The second stage consists of activated carbon drums for the removal of the organic sulfur compounds. The activated carbon is reactivated with steam when required. Both stages of sulfur removal are arranged so that the plant need not be shut down when they are being recharged or reactivated.

The desulfurized feedstock is mixed with steam, which has been superheated by heat exchange with the furnace flue gases, and introduced into the hydrogen furnace tubes. This furnace consists of a vertical combustion chamber in which are suspended a number of centrifugally cast alloy tubes containing a nickel base catalyst for promoting the steam-hydrocarbon reactions:

$$C_nH_{2n+2} + nH_2O \rightarrow nCO + (2n+1)H_2$$
$$C_nH_{2n+2} + 2nH_2O \rightarrow nCO_2 + (3n+1)H_2$$

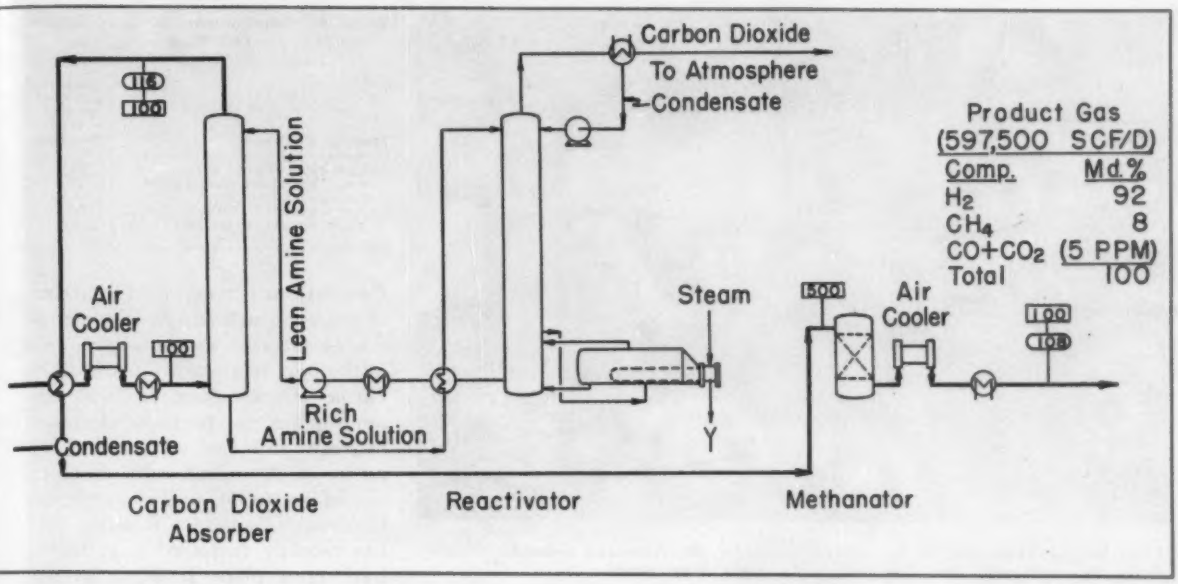
These reactions are carried out at approximately 1,350 F. and are highly endothermic. The heat thus required is supplied by burning fuel and gas in the combustion chamber of the furnace.

As may be seen by the above equations, the products of the reaction are hydrogen, carbon monoxide and carbon dioxide. Since hydrocarbon impurities in the product hydrogen are not detrimental to the refining process, a considerable amount of methane is allowed to remain in the reformer furnace effluent gas thus permitting the furnace to operate at higher space velocities and lower temperatures than normally used in high purity hydrogen plants. These, in turn, permit the use of fewer catalyst tubes and a longer tube life. The approximate composition (dry basis) of the gas from the reformer furnace is given in column (1) of Table 2:

TABLE 2—Process Gas Analyses (Dry Basis)

Components	CONCENTRATION, VOL. %			
	From Reformer Furnace (1)	From Converter (2)	From Absorber (3)	Hydrogen Product (4)
H_2	70.2	72.5	92.33	92
CO	9.2	0.9	1.15	≤5 ppm
CO_2	15.1	21.5	0.05	
CH_4	5.5	5.1	6.47	8
Total..	100.0	100.0	100.00	100

The gas coming out of the furnace is cooled, by the addition of condensate and steam, to the temperature required for the carbon monoxide conversion operation that follows. In



pressure to take advantage of the available pressure of the feedstock and thus save in subsequent hydrogen compression costs.

this step the carbon monoxide present in the gas reacts with steam to produce additional hydrogen according to the following reation:

$$CO + H_2O \rightarrow CO_2 + H_2$$

This reaction takes place in the converter over a promoted iron oxide catalyst at approximately 700 F. By this point the pressure of the gas stream has been reduced to approximately 120 psig. The composition of gas coming out of the converter is approximately as shown in column (2) of Table 2.

Due to the exothermic nature of the carbon monoxide conversion reaction, the gas temperature is increased in the converter, and the gas emerges at about 750 F. Prior to carbon dioxide removal, the heat is removed by heat exchange with the gas coming out of the carbon dioxide absorber, followed by two coolers, the first using air cooled finned surface and the second using cooling water.

Carbon dioxide removal in the American Gilsonite plant is accomplished by the Girbotol process, which uses an aqueous solution of monoethanolamine to absorb the carbon dioxide according to the following reaction:

$$2RNH_2 + CO_2 + H_2O \rightarrow (RNH_3)_2CO_3$$

(R is in an organic radical)

The reaction proceeds to the right at temperatures around 100 to 150 F. and thus the carbon dioxide reacts with the amine in the absorber and is removed from the converted gas stream. The reaction is reversed at higher temperatures in the reactivator and the carbon dioxide thus released is stripped out of the ethanolamine solution and discharged to the atmosphere. The lean solution from the reactivator is recycled to the absorber. The gas composition after carbon dioxide absorption is approximately as given in column (3) of Table 2.

Since the refining process used at Gilsonite requires a minimum of carbon oxides in the product gas, these are reacted with hydrogen in

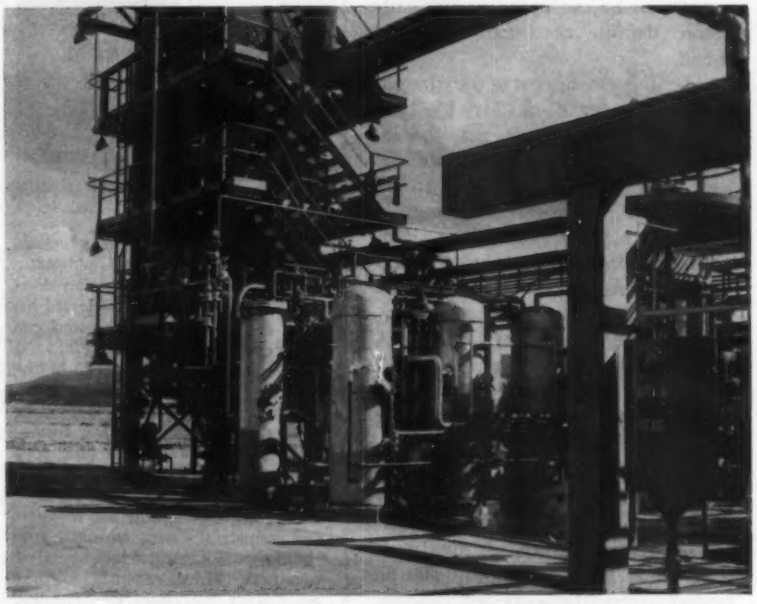


FIGURE 3—Hydrogen is produced from hydrocarbons in this pressure reformer furnace at American Gilsonite refinery. Caustic scrubbers and activated carbon drums for removing sulfur from the feedstock are in the foreground.

FIGURE 4—This view of the control room for the American Gilsonite refinery shows the hydrogen plant controls on the right hand panel.

a methanation step according to the following reactions:

$$CO + 3H_2 \rightarrow CH_4 + H_2O$$
$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

These reactions take place in the methanator over a nickel catalyst at elevated temperature. The gas is preheated to approximately 500 F. by heat exchange with the gas leaving the carbon monoxide converter prior to entering the methanator. The above reactions are exothermic. Thus the temperature of the gas leaving the methanator is approximately 650 F. at design conditions. This heat is removed from the product by a combination of air and water cooled units.

The product gas from the hydrogen plant delivered to the refining operations at 108 psig and 100 F., has approximately the composition listed in column (4) of Table 2.

Operating Requirements. When operated at rated capacity the raw materials and utilities required by the American Gilsonite hydrogen plant are given in Table 3.

TABLE 3—Requirements for American Gilsonite's Plant at Rated Capacity

Material Required	Quantity per 1,000 SCF* of Product Gas
Feed gas **, scf	152
Fuel gas (1380 Btu/scf), scf	160
Steam (150 psig, saturated), lbs	250
Electric power (440 v, 3 ph.), Kwh	0.7
Cooling water (75F., 40F. rise), gals	765
Caustic soda, pounds	0.645
Monoethanolamine, pounds	.004

* scf = cubic foot measured at 60F. and 1 atm.

** Based on gas feed composition given in Table 1.

What Hydrogen Costs. By tailoring the plant specifically to the capacity and purity requirements of the refiner, it is possible to produce hydrogen at a direct cost of 15 cents to 20 cents per thousand cubic feet and a total cost, including fixed charges, of 25 cents to 35 cents per thousand cubic feet. Each case, however, must be evaluated individually before definite costs can be established.

The investment cost of a hydrogen plant will vary considerably and quality of the product gas, the locality and the specifications of the user. On the basis of 90 to 95 percent pure hydrogen using normal chemical plant specifications, it is estimated that a hydrogen plant similar to American Gilsonite's can be supplied on a battery limits, erected basis for about $500,000. A plant capable of producing 10 million cubic feet per day of 90 percent hydrogen will cost approximately $2 million.

Feedstock and utility requirements for a 10 million cubic feet per day plant are shown in Table 4.

This type of plant includes a waste heat boiler to supply all the steam required by hydrogen production. Operating labor requirements amount to one to two men per shift.

TABLE 4—Requirements for a 10 Million CFD Plant

Material Required	Quantity per 1,000 SCF of 90% Hydrogen
Natural gas (175 psig), scf	325
Fuel gas, M Btu net heating value	225
Electric power, kwh	0.4
Cooling water (85F., 20F. rise), gals	700
Boiler feedwater (250 psig, 200F), lbs	92

Conclusion. It is expected a number of refineries will add hydrogen producing facilities to their operations in the next few years. For example, Girdler Construction Division has also supplied two pressure reforming hydrogen furnaces, with a total capacity of 30 million cubic feet per day of hydrogen, to Tidewater Oil Company's Delaware refinery, and has recently furnished a complete hydrogen plant Irving Refining, Ltd., St. John, New Brunswick, with a capacity in excess of 3 million cubic feet per day of 90 percent hydrogen. The current trend toward hydrogen treating of refinery streams for feedstock preparation and product up-grading will continue to increase the need for supplemental hydrogen.

About the Author

Norman C. Updegraff is technical representative for Chemetron Corp.'s Girdler Construction division, Louisville, Ky. Holder of an A.B. degree in chemistry and engineering sciences from Harvard University, he was with E. I. du-Pont de Nemours & Co. from 1942-46 as a production supervisor in neoprene manufacture, Louisville. He then joined Girdler, specializing in the development and design of processes for the production, purification and use of various industrial gases, synthesis ammonia, petrochemicals and related products. More recently he has been with the Sales department. Updegraff is a member of ACS and AIChE.

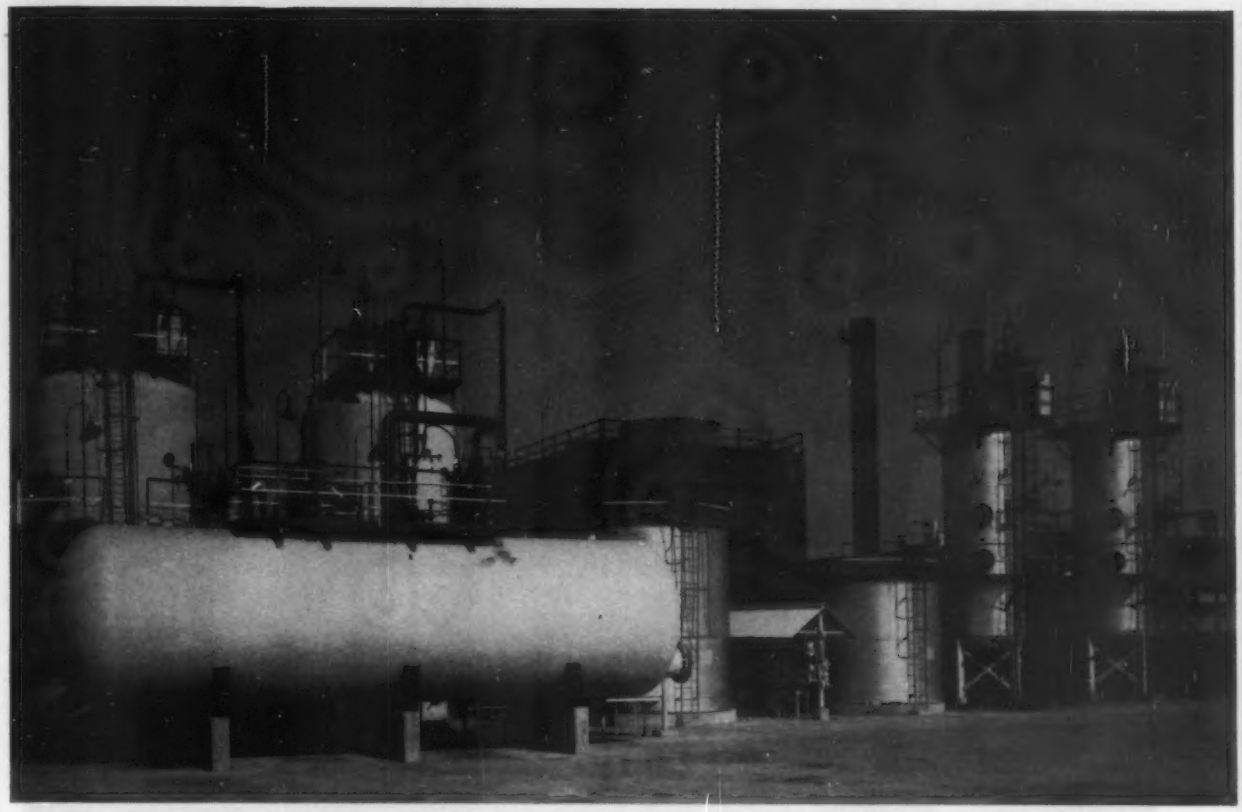


FIGURE 1—Four of the Electrofining treaters are two-stage units and one is a single-stage unit.

Richfield Treaters Have Flexibility

Five Electrofining treaters and a Bender catalytic sweetener have been constructed for this refinery. Here is how they treat 19 streams in units occupying only a total ground space of a 50- by 100-foot lot

L. J. Gandsey, Richfield Oil Corp., Watson, Calif.

R. L. Pettefer, Petrolite Corp. Long Beach, Calif.

A STEADILY INCREASING market demand for its products has caused the Richfield refinery at Watson, Calif., to require additional treating facilities. To fulfill this need, five Electrofining treaters and a Bender catalytic sweetening unit have been installed during the period 1955 to 1958.

These six treating units were installed on a plot of ground equal to a 50-foot by 100-foot lot and are capable of processing more than 60,000 bpd of distillates. General views of these units may be seen in Figures 1 and 2.

Table 1 summarizes the streams which are treated, the reasons for treating and the end use of the treated distillate.

Operating Principle. Four of the Electrofining treaters are two-stage units and one is a single-stage unit. The various types will be discussed in detail later. Each treating stage, however, operates on the same principle.

In each stage, the distillate is vigorously emulsified with a reagent, such as acid, caustic, or water. The emulsion is then conducted through

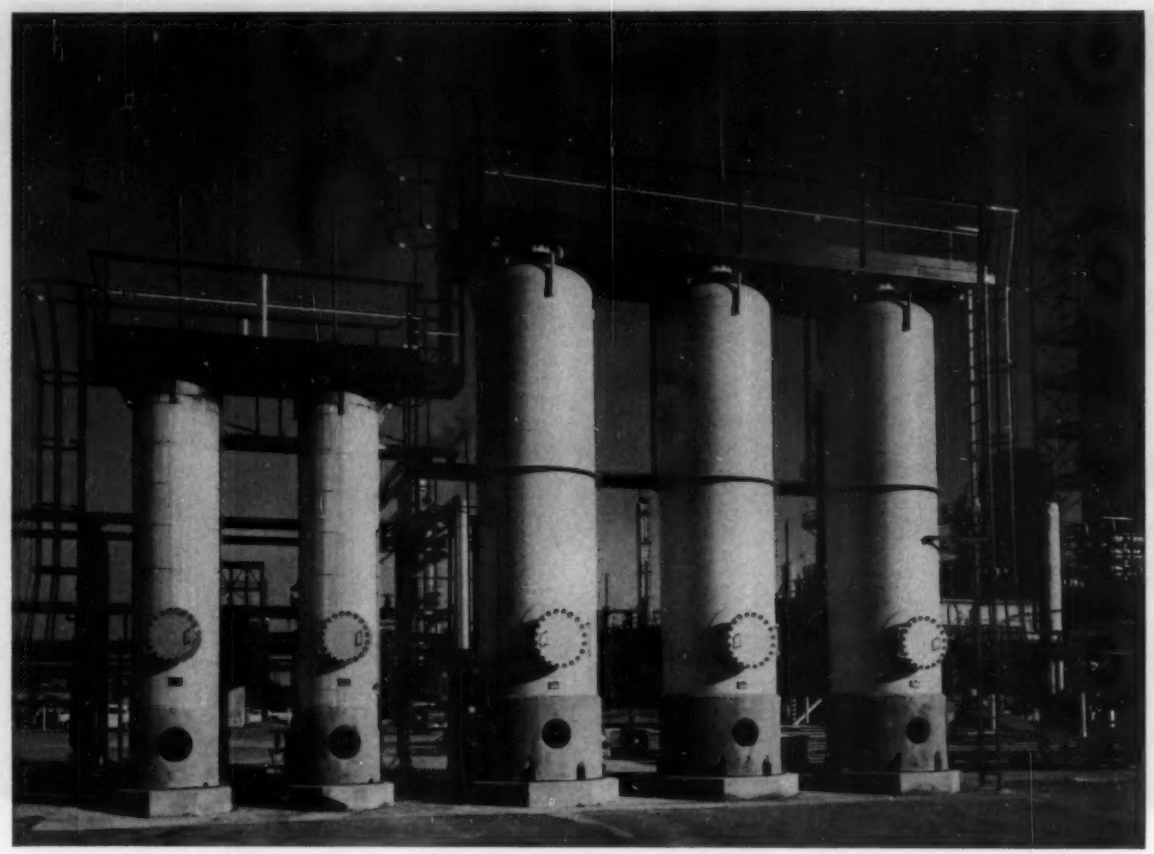


FIGURE 2—The vessels used in the Bender sweetener consist of two sulfur absorbers and three catalyst towers.

a high voltage field where the spent reagent droplets fall to the bottom and the purified distillate flows out of the top of the vessel.

Each treating stage is equipped with a 5 KVA (maximum demand) power supply which furnishes direct current power of high voltage to the electrode system inside the vessel. The average operating loads range from 0.5 to 2.0 kilowatts for each treating stage.

Stove Oil—Jet Fuel Treater. In 1957 Richfield examined its treating facilities for jet fuel components in view of the more stringent specifications that were to be imposed on these fuels. As a result of this study, a two-stage acid-caustic Electrofining unit was installed. It is powered by two high-voltage d.c. power packs fed directly by the refinery's 460 volt a.c. line. A flow diagram is shown in Figure 3.

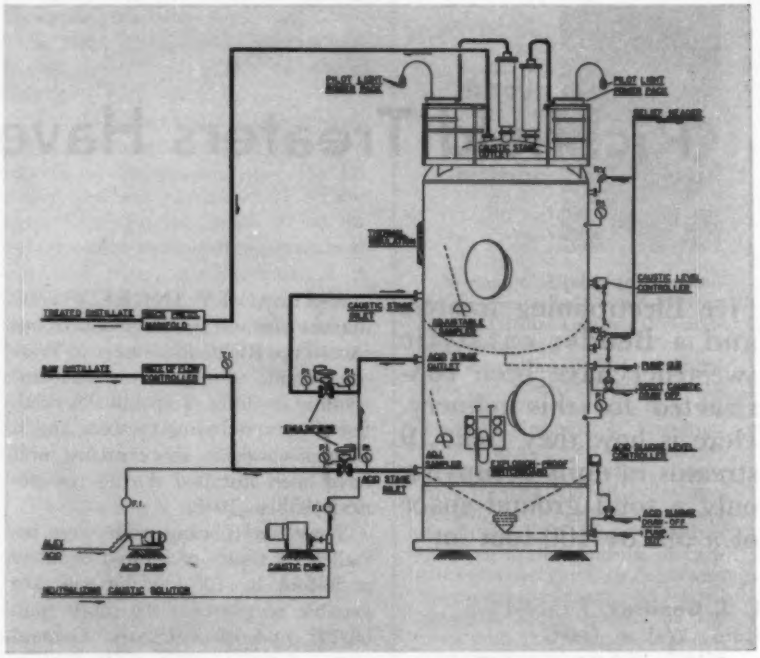


FIGURE 3—The stove oil treater is powered by two high-voltage d.c. power packs fed directly by the refinery's 460 volt a.c. line.

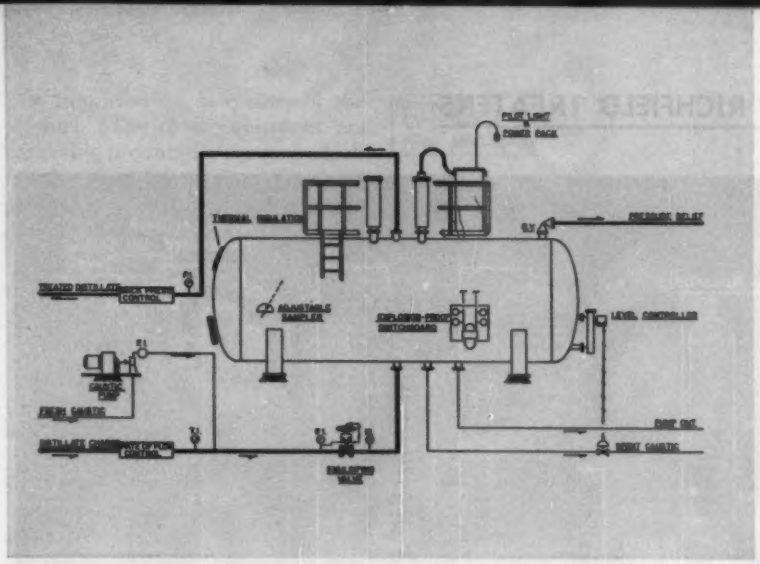


FIGURE 4—This single-stage unit gives a caustic wash to the straight run diesel oil which is produced from five crude distillation units.

Treatment is continuous, the charge pump feeding the treater on flow control from a local surge tank. Various fractions from selected crudes flow into this surge tank. Spent acid from the alkylation units is injected continuously into the feed stock at the desired dispersion followed by the required intense mixing condition. The quantity of acid used in this treater will vary from 1 pound per barrel to 5 pounds per barrel, depending on stock treated and results desired. The oil-acid mixture is then subjected to the action of the electric field, which coalesces the acid and removes it from the oil so that the oil phase carries less than 0.001 volume percent acid when leaving this electric precipitator. The acid sludge effluent contains less than 0.04 percent of entrained oil.

Instrumentation automatically controls the desired degree of acid dispersion and time of contact. These controlled conditions, along with the rapid separation of the acid sludge from the stock, made possible by the electrical field, result in the efficient removal of the oil-soluble impurities, producing a desirable product. This method of treating also limits the loss of product to the acid sludge to a very low value as stated above.

The acid used in this treater as well as in the two-stage Electrofining unit for cycle oil is taken from the alkylation units at about 89 percent acid strength. The acid-sludge level is effectively controlled with a conventional level controller. Because of the rapid separation of the spent acid from the oil in the elec-

Summary of Advantages Gained by Treaters

Improved Product Quality. The jet fuel passed all specifications without "retreating." The treated products had better storage stability. The treated products contained less sodium, less naphthenic acid, less mercaptans, less sulfur, and less color bodies.

Fouling Minimized. Efficient removal of spent caustic from SR gasoline minimized fouling of exchangers and re-boilers in fractionating equipment.

Savings in Ground Space. Six treating plants occupying a total ground space equal to a 50-foot by 100-foot lot blend and treat 19 streams and have a treating capacity in excess of 60,000 barrels per stream day.

Intermediate Storage Eliminated. "On-Stream," continuous treating and blending has largely eliminated the need for intermediate tank storage.

Savings in Chemicals. Efficient treating substantially reduced the chemical consumption.

Savings in Labor. Automatic operation reduces labor requirements and gave more efficient operation.

No Air Pollution. Vapor-tight equipment prevents air pollution.

Waste Water Treating Minimized. Efficient electrical precipitators removed spent reagents from distillates and only negligible amounts reached the water wash stage.

Low Product Loss. The total loss for the entire installation is low because efficient electrical separation left only negligible amounts of oil in the spent reagents.

Low Maintenance Cost. The treating units are on an annual turnaround schedule and repairs have been minor.

Operating Personnel. Become proficient at treating.

Flexibility. The equipment is capable of producing a wide variety of products and the centralized location permits blending of components on a continuous basis as desired.

Cleanliness and Safety. These items go hand in hand. The photographs clearly show the cleanliness of this vapor-tight equipment.

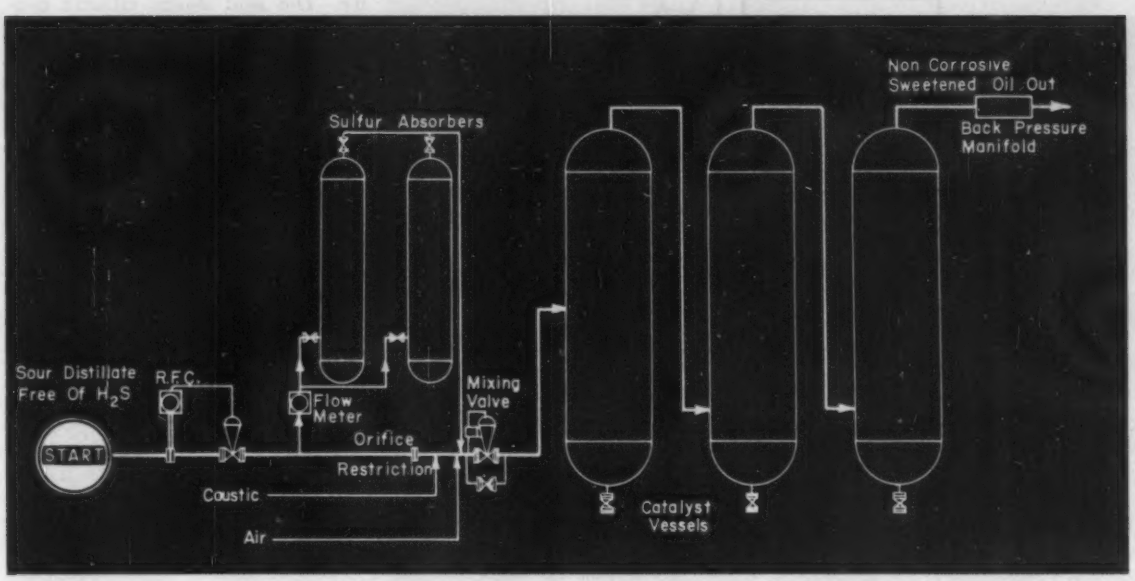


FIGURE 5—The mercaptan content of the untreated stock determines the quantity of sulfur, caustic and air to be used.

tric precipitator, polymerization of organic matter in the spent acid is minimized so that the acid sludge is quite fluid.

The acid sludge from the treater is pressured into a sludge storage vessel where it is blended with sludge from other treating operations. Corrosivity of the acid sludge removed from the treater is negligible because the acid is diluted primarily with hydrocarbons. Special protection against corrosion is given only to the inlet line into the second stage at the point of caustic injection.

The treated distillate which leaves the acid treating stage is neutralized in the second stage of the treater. In this stage a weak caustic of 3° to 5° Be′ is used to neutralize the small amount of residual acid from the first stage. The caustic stream is injected continuously at the desired pressure to insure adequate dispersion and the oil-caustic mixture is mixed further under controlled conditions to insure complete neutralization.

The oil-caustic mixture is introduced into the electric field where the dispersed weak caustic phase is coalesced and separated from the oil. The product leaving the treater has a sodium content of only 1 ppm. The spent caustic is continually withdrawn by automatic level control. This spent caustic is dropped directly to the sewer which empties into the refinery's waste water treater. The oil content of this spent caustic is less than 0.04 volume percent, and hence minimizes waste water treating problems.

Furthermore, treating losses of product have been reduced to 0.63 volume percent by the installation of this new treating method in comparison with the 1.0 volume percent loss experienced previously.

The unique advantages of this Electrofining unit as compared to the equipment that it replaced are as follows:

- Significant savings in chemical consumption.

TABLE 1—Streams Being Treated

Raw Stock	Reason for Treating	Use of Treated Stock
Gasoline from 4 crude units; 335° F. E.P.	To remove hydrogen sulfide.	Gasoline blending. Feed for fractionation of selected components.
Stove Oil fraction from 5 crude units	To stabilize color, meet water tolerance specification, meet *CFR fuel coker specifications, and reduce sulfur content.	J.P. #4 Blending Component, J.P. #5 Commercial Jet Fuel Stove Oil
Diesel oil fraction from 5 crude units	To remove naphthenic acids, and improve stability of product.	Commercial diesel and Burner Fuels.
Cycle Oil from three catalytic cracking units	To remove nitrogen compounds and color bodies, reduce sulfur, and increase stability of product.	Burner fuel Economy diesel
Sour stove oil fraction from two crude units	Oxidize mercaptan sulfur to disulfide	Blending components for jet fuels Stove Oil.

* Coordinating Fuels Research (thermal stability test).

TABLE 2—Physical Description of Treaters

Treaters	Plot Area, Sq. Ft.	VESSELS No.	Dia., Ft.	Ht. or Lgth., Ft.
Stove Oil–Jet Fuel	625	1	8	22
Cycle Oil	625	1	8	20
Gasoline	500	1	12	20
Gasoline	500	1	12	20
Diesel Oil	600	1	10	20
Bender	1200	5	2 @ 3.5 3 @ 6	14 20

• Improvement in quality of the jet fuel. (The older equipment occasionally produced a product which failed to pass certain specifications, and hence had to be treated a second time.)

• Treated jet fuel from the Electrofiner goes directly to finished products tanks and passes all specifications for jet fuel.

• Treating losses were reduced from 1.0 volume percent to .63 volume percent.

Cycle Oil Treater. The purpose of treating cycle oil is to produce a stable product which can serve as a component for locomotive diesel fuel or a No. 2 burner oil.

The "cycle oil treater" is identical with the one described previously under the heading "stove oil treater," hence no description of equipment or processing will be given here. (See Figure 3.)

The feed to this treater can be a blend of cycle oil from the fluid catalytic cracking unit and from either of the two TCC units. The streams flow directly from the catalytic cracking units into the treating unit, thereby eliminating all intermediate storage.

The oil is treated with 3 to 5 pounds of spent alkylation acid per barrel, followed by neutralization with dilute caustic.

Results of the stability test on the treated cycle stock indicate that this acid-treating, followed by a caustic wash is satisfactory for producing a stable product. Gum values after three months storage of the treated cycle stocks fell within the range of values that were obtained from straight run diesel stocks. Colors of 3½ N.P.A. were obtained on the treated cycle stock after a three months storage period. This color stability is as good as or better than that of straight run diesel oil as compared in Table 3.

Straight Run Gasoline Treaters (Two Identical Units). These two-stage Electrofining units were installed for the purpose of giving a 7.5° Be′ caustic wash, followed by a water wash, to the straight run gasoline, which is produced from five crude distillation units. The purpose of this treatment is to remove hydrogen sufide. Residual sodium is less than 0.2 ppm and water carryover is nil because of efficient precipitation.

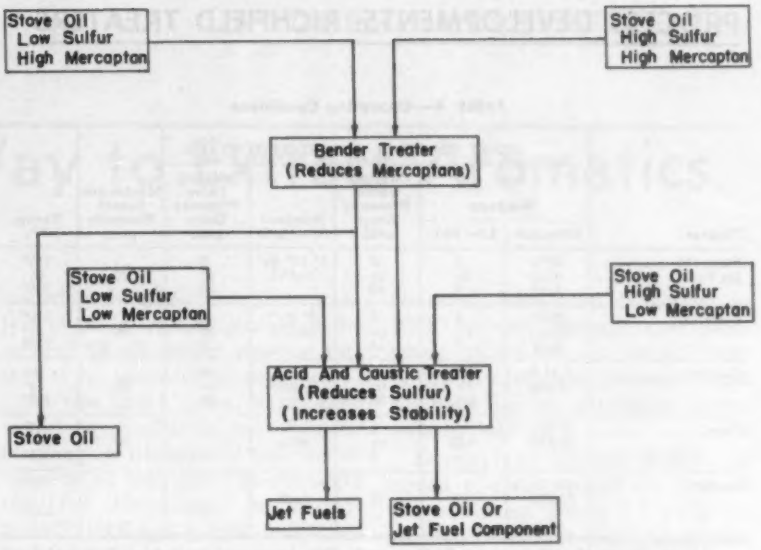


FIGURE 6—Flexibility is achieved by having the Bender treater upstream of a two-stage acid treater.

This degree of purity is important because, following this treatment, a substantial portion of the naphtha, after being fractionated, is charged to a hydrodesulfurizer and catalytic reformer. Any carryover of sodium would be objectionable because the sodium salts would cause fouling of heat exchanger and reboiler tubes in the fractionating equipment, and would also damage the catalyst.

This treater has been in operation for several years, and the catalyst life at the reformer has been highly satisfactory.

Diesel Oil Treater. This is a single-stage Electrofining unit installed for the purpose of giving a 3° Be′ caustic wash to the straight run diesel oil which is produced from five crude distillation units. The purpose of this treatment is to remove naphthenic acids and to stabilize the product. (See Figure 4.)

3° Be′ caustic is injected at about 10 percent excess of the amount necessary to neutralize the oil acidity. Better than 95 percent acid oil removal is experienced and the amount of alkalinity in the spent caustic is very small.

The special benefits derived from the diesel treater are as follows:

• Greater efficiency in recovery of naphthenic acid.

• Increased stability of treated stock.

• Less neutral oil in the caustic extract.

TABLE 3—Comparing Cycle Oil With Straight Run Diesel

	Straight Run Diesel	Untreated Cycle Oil	Treated Cycle Oil
Color, N.P.A.			
Fresh	2½	2+	1+
After 1 month @ 110° F.	3½	8+	2½
After 3 months @ 110° F.	4½	8+	3½
Gum, Mg/100 ml.			
After 3 months @ 110° F.	1.4	8.5	1.7

Bender Treater. Because of the prospect of processing sour crude oils which would produce sour distillates, and because the refinery had no treating facilities to sweeten the middle range of distillates, a study was conducted which resulted in a decision to use the Bender sweetening process. This treater consists of three catalyst vessels 6 feet in diameter by approximately 14 feet high. (See Figure 5.)

The stove oil from sour crudes is high in both mercaptan sulfur and total sulfur. Stove oil as produced from the crude distillation units on sour crude has as much as 0.012 wt. percent mercaptan and 0.35 wt. percent total sulfur. This stock is Bender treated to reduce the mercaptan sulfur to less than 0.0004 wt. percent and then acid treated and neutralized in a two-stage Electrofining unit which reduces the total sulfur to 0.25 wt. percent. This treated stock can then be used as a

TABLE 4—Operating Conditions

Treater	FIRST STAGE Reagent Strength	FIRST STAGE Reagent Lbs/Bbl.	FIRST STAGE Mixing Valve Pressure Drop psig	SECOND STAGE Reagent Strength	SECOND STAGE Mixing Valve Pressure Drop psig	Minimum Vessel Pressure psig	Temp. °F.
Stove Oil..... Jet Fuel.....	89% Alky-Acid	1 to 5	3 to 10	3°-10° Be' NaOH	3 to 30	.. 30	110° to 130°
Cycle Oil.....	89% Alky-Acid	3 to 5	5 to 15	5° Be' NaOH	3 to 5	30	120° to 175°
Gasoline.....	7.5° Be' NaOH	0.03 to 0.12	15 to 25	Water	10 to 20	25	90° to 100°
Diesel.....	5° Be' NaOH	0.09	1 to 3	none		30	85° to 95°
Bender*.....	18° Be' NaOH	.06	18	none		25	110° to 120°

* In this Bender plant the amount of sulfur used is .004% by wt., and the amount of air used is one-half of a standard cu. ft. of air per bbl. of distillate (These figures vary with RSH content).

TABLE 5—Product Analyses of Treated Oils

	Boiling Range °F.	Sodium, ppm.	Corrosion	Mercaptan Sulfur, Percent	Existent Gum mg/100 ml.
Stove Oil.....	330° to 530°	1.1	1A	0.0004	1
Cycle Oil.....	425° to 610°	2.0	1B	.....	..
Gasoline.....	335° E.P.	0.2	1A	0.0001	1
Diesel.....	450° to 650°	1.0	....	.....	..
Stove Oil–Bender Treated.....	330° to 530°	1.0	1A	0.0001	1

component for jet fuels or as a marketable stove oil.

Sulfur and mercaptan content of stove oil fractions from different crudes vary independently of each other. Figure 6 illustrates the degree of flexibility in treating which is derived from having a Bender treater upstream of a two-stage acid treater. This flexibility is necessary because of the wide variety of crude oils processed.

Prior to Bender treating, the raw charge stock is given a simple, single-stage caustic wash for the purpose of removing hydrogen sulfide and naphthenic acids, because these impurities would interfere with the sweetening process.

The charging stock is produced from one of two crude units and is sent through the Bender unit at a uniform feed rate and at a controlled temperature of 110° to 120° F. This temperature is maintained through an exhaust steam preheater located downstream of the charge pump.

The mercaptan content of the untreated stock determines the quantity of sulfur, caustic and air to be used. The quantities of these reagents are regulated by controllers which allow them to flow into the untreated stock. They are thoroughly mixed with the stock by means of a mixing valve. The distillate passes through the three successive catalyst beds in series from the bottom of each catalyst bed to the top. The sweet non-corrosive oil from the final catalyst bed then flows to storage.

The use of chemicals for this unit is limited to sulfur, caustic, catalyst and air. The quantity of sulfur required for treatment is governed by the type of distillate and its mercaptan content. The sulfur is supplied by diverting a small slip stream from the raw charging stock downstream of the preheater through one of the two sulfur absorber towers.

The caustic requirement of the system is very moderate (usually 5 to 10 ppm by weight on the basis of the total distillate). This amount will vary with the mercaptan content of each stock. It is added to yield a product from the first catalyst bed which is slightly positive to phenolphthalein. The treated stock leaving the last catalyst bed has a sodium content of less than 1 ppm, is bright, sweet, and non-corrosive.

The catalyst is supported in the tower as a fixed bed. This catalyst bed is made up of uniform particles which consist of porous pellets ⅛-inch to ¼-inch in size, which have been coated with lead salts. The catalyst activity has not shown any measurable drop since the unit was placed on stream over ten months ago.

A summary of operating conditions for the Electrofining units is given in Table 4. Analyses of products from the foregoing treaters are shown in Table 5. Lastly, a summary of the advantages for these installations is given in the accompanying box.

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A Better Way to Extract Aromatics

A new solvent, sulfolane, has been tested as a substitute for diethylene glycol. Here is a report on how well the new solvent will extract aromatics for BTX production or for motor fuel octane improvement

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Shell Development Company
Emeryville, Calif.

THE EXTRACTION of catalytic reformates to produce an aromatic extract of high octane rating for motor gasoline blending offers promise as an economical means for obtaining the higher octane premium gasolines estimated to be required in the future. Shell Development Company has developed a commercial process for manufacturing sulfolane, a solvent which has superior properties for the extraction of aromatics from hydrocarbons in the gasoline boiling range.

This article gives basic properties of sulfolane and compares it with diethylene glycol. Pilot plant data are presented for sulfolane extraction to produce an extract having a 105.4 Research octane number at 3 ml TEL/gal. from a reformate feed having a 96 leaded Research octane. Also bench scale data are presented for sulfolane extraction to produce high purity aromatics. Then commercial process designs for each of these applications are compared with those for diethylene glycol.

Predictions by various experts[1,2,3] report premium gasoline Research ratings as high as 104-107 at 3 ml TEL/gal (Wiese scale) will be required by the mid-1960's. Incorporation of the extraction process in the refinery would permit gasoline ratings to be increased to this level.

At the same time, a raffinate would be produced suitable for blending in housebrand gasoline or military jet fuel, JP-4. The demand for JP-4 is estimated[4] to increase from 250,000 bpd in 1958 to 390,000 bpd in 1963. At present, much of the military jet fuel is supplied directly from straight-run fractions which have a high octane potential if catalytically reformed. Hence, backing out these fractions from jet fuel, reforming them, and substituting raffinate from the extraction plant would increase the refinery octane potential.

Furthermore, the recovery of benzene, toluene and xylenes (BTX) from catalytic reformates and straight-run fractions is already an important refinery operation. The U. S. capacity for these aromatics in 1959 will be 750 million gallons per year,[5] representing an increase of 100 milion gallons per year over the capacity in 1957. It is predicted the 1959 capacity will be more than sufficient to supply the anticipated demand for BTX through 1965.

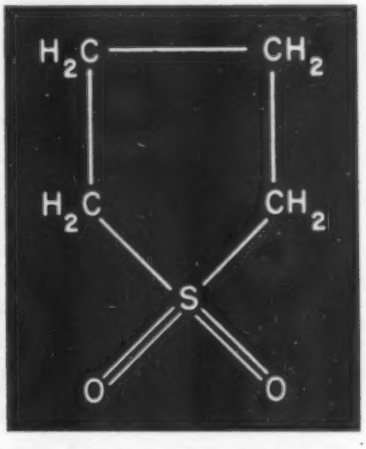

FIGURE 1—Successful techniques have been developed for producing sulfolane.

However, substantial economies in BTX recovery through new processing techniques or development of new uses for these aromatics could stimulate further processing extensions in this field.

Diethylene glycol (DEG), or mixed glycols, is used[6] in most of the extraction plants for BTX recovery. DEG has also been proposed[6] for the extraction of catalytic reformates for the octane improvement of motor gasoline. However, another solvent, sulfolane, has been developed for these applications by Shell Development Company with the assistance of Shell Oil Company. Bench scale and pilot plant data indicate sulfolane is superior to DEG in many cases.

Sulfolane, the cyclic C_4 sulfone, has the structure shown in Figure 1. It is made by reacting one molecule of SO_2 with one molecule of butadiene to form sulfolene which is hydrogenated to sulfolane. Shell Development Company has developed successful techniques for manufacturing sulfolane in pilot plant operation. Plans for manufacture of commercial quantities of sulfolane are under consideration.

SULFOLANE IS BETTER

The properties of sulfolane are compared with those of DEG in an accompanying box. A summary of this comparison indicates the following key differences:

- Sulfolane is more selective (except near the plait point).
- Sulfolane-hydrocarbon systems have a plait point.
- Hydrocarbons are much more soluble in sulfolane.
- Hydrocarbons have a higher partial pressure over DEG, although hydrocarbon/solvent relative volatilities are about the same for each.
- Sulfolane has a much lower partial pressure at low concentrations in extract components.
- Sulfolane is more heat and oxi-

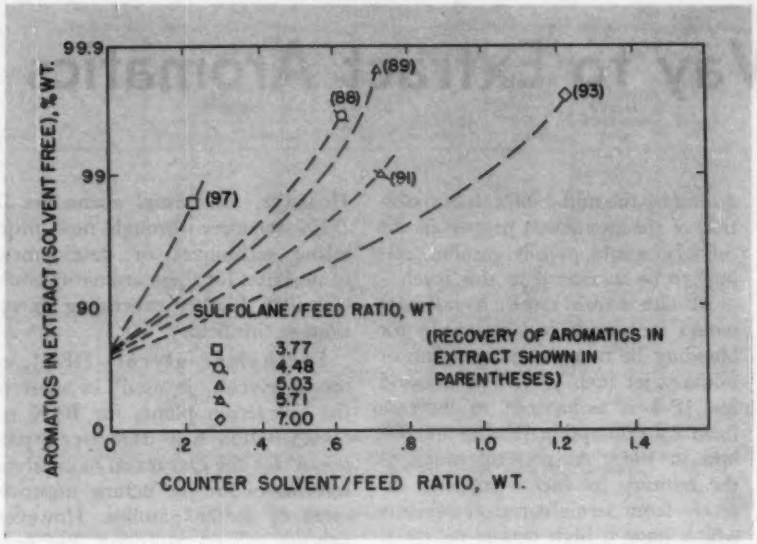

FIGURE 2—These data were obtained at an extraction temperature of 212 F.

dation stable than DEG and has a lower heat capacity.

- The distribution coefficient for solvent between water and hydrocarbon is much higher for DEG.
- Sulfolane has a higher melting point than DEG.

These key differences lead to somewhat different aromatic extraction processes for the two solvents. These differences can best be explained by reviewing the two main applications of this extraction technique—one for making high purity aromatics and one for high octane improvement.

FOR HIGH PURITY AROMATICS

The extraction of a light reformate having the composition shown in Table 1 has been studied on bench scale. Extraction and backwashing studies were carried out in an integrated operation using separate centrifugal contactors for each. For this operation a 460 molecular weight paraffinic countersolvent was used as the backwash agent to obtain high extract purity.

TABLE 1—Feed Composition—Extraction for High Purity Aromatics

Carbon No.	WEIGHT PERCENT		
	Saturates	Aromatics	Total
C_5.....	1.6	...	1.6
C_6.....	6.4	7.3	13.7
C_7.....	15.7	20.0	35.7
C_8.....	14.8	25.2	40.0
C_9.....	5.5	3.5	9.0
Total....	44.0	56.0	100.0

Figure 2 shows typical data obtained in this study when using sulfolane containing 1.3 weight percent water and an extraction temperature of 212°F. Correlation of these data indicates that a 99 percent aromatic extract can be obtained at 95 percent aromatic recovery using a solvent/feed weight ratio of 6.8 and a countersolvent/feed weight ratio of 1.0. A smaller backwash/feed weight ratio could be used with lower molecular weight countersolvents since purity is determined (at a given solvent rate) by the moles of backwash per mole of feed.

Process Design. Figure 3 shows the flow scheme for a process designed to recover 95 percent of the feed aromatics at 99 percent purity from a light reformate having composition similar to that shown in Table 1 using a narrow boiling paraffinic countersolvent fraction averaging sixteen carbon atoms to obtain extract purity. For this countersolvent the required countersolvent/feed ratio will be only half of that determined experimentally for the 460 molecular weight countersolvent.

The feed enters a rotating disc contactor (RDC) which includes an extraction section, a backwash section, and top and bottom settlers. The fat solvent from the extraction section, which contains the bulk of the aromatics in the feed and a portion of the saturates, flows down into the backwash section where counter-

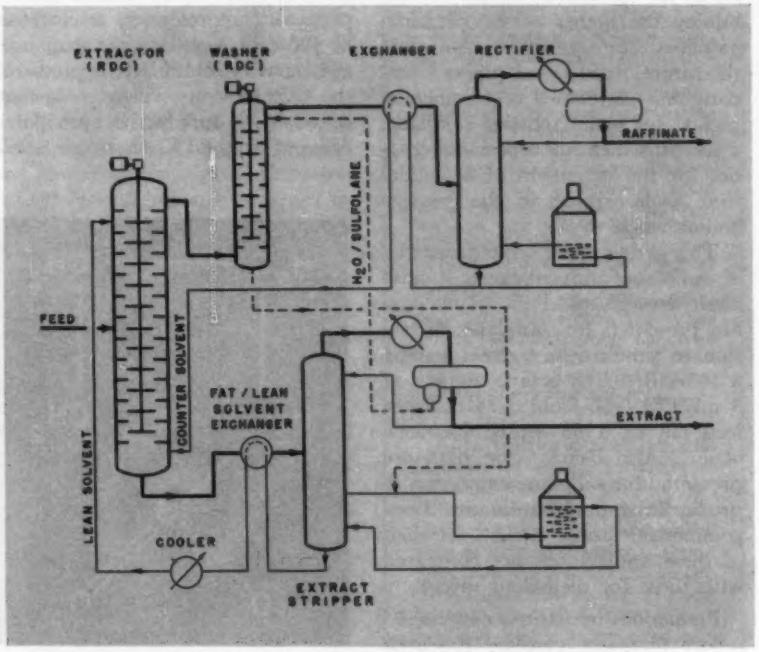

FIGURE 3—The total capital requirement for the sulfolane process will be only about 75 percent of that required for the diethylene glycol process.

current contacting with the heavy countersolvent removes the saturated components. The fat solvent from the backwash section, which now contains 1 percent saturates (exclusive of heavy countersolvent) basis total hydrocarbons, passes through a surge vessel and a fat solvent/lean solvent exchanger to the stripper.

Extract is recovered from the fat solvent (99.9 percent C_8 aromatics overhead) by stripping with steam from the direct-fired stripper reboiler. The raffinate is water washed and separated from the countersolvent as an overhead product.

Process conditions and utility requirements for the sulfolane process are shown in Table 2. For comparison, similar data estimated for a process using DEG/water as the solvent at the same recovery and purity are also shown. The DEG process uses a light extract, generated by partial flashing and stripping of the fat solvent, as the backwash medium and the temperatures of extraction and stripping are maintained at about the same level. The DEG process uses steam for heating whereas the sulfolane process requires direct fired reboilers to achieve higher reboiler temperatures.

The utilities and relative capital costs shown are for the extraction portion of the plants and do not include clay treating and fractionation facilities necessary to recover nitration-grade benzene, toluene and xylenes as separate fractions. These latter facilites would be expected to be the same for either process.

Utilities required for the sulfolane process are substantially lower than for the DEG process. This is mainly due to the lower solvent rate for sulfolane (about 35 percent of that required for DEG) which, together with the lower heat capacity of sulfolane, permits operation of the stripper at higher temperature to reduce the water content of the lean solvent (which minimizes the process heat load) and the extractor at lower temperature to maximize solvent selectivity.

It is estimated that the total capital required for the sulfolane process will be only 75 percent of that required for the DEG process. The big difference in capital costs lies in the cost of utilities. Because of the much higher heat load required in the DEG process, the cost of facilities for steam generation is quite high and more cooling water tower capacity is required.

Capital and operation costs of the sulfolane process can be reduced compared with those shown above for the heavy countersolvent process by using a special technique for preparing a backwash rich in saturates directly from the fat solvent. Further discussion of this alternative technique is reserved at this time. Use of mixed glycols instead of DEG, as is the current trend in commercial processes for obtaining high purity aromatics, will result in economies over the use of DEG alone, narrowing the advantage of the sulfolane process somewhat.

In addition to manufacturing high purity BTX, sulfolane processes are expected to prove equally attractive for recovering benzene, toluene, xylenes or C_9 aromatics in high purity either separately or in various combinations.

TABLE 2—Comparison of Sulfolane and DEG Extraction—Nitration-Grade Aromatics

	DEG	Sulfolane
Operating Conditions		
Solvent/feed ratio, wt	20	6.8
Backwash/feed ratio, wt	1.1	0.5
Stripping steam/feed ratio, wt	0.6	0.13
Stripper bottom temperature, °F	290	375
Extractor top temperature, °F	290	212
Extractor pressure, psig	110	15
Feed temperature, °F	240	240
Water content of lean solvent, %wt	7.5	1.3
Utility Requirements/bbl Feed		
Steam, lb	400	2.5
Fuel, M Btu	....	190
Cooling water, gal	1,200	530
Electric power, kwh	1.3	0.8
Total Process Heat Duty, M Btu/bbl feed	370	130
Total Capital,* relative to DEG process	1.0	0.75

* Including the cost of offsite facilities and utilities based on 1,650 bbl/sd feed.

FOR OCTANE IMPROVEMENT

Low pressure catalytic reforming (200-400 psig reactor outlet pressure) is recognized as one of the most attractive alternatives for obtaining the high octane ratings in premium gasolines anticipated to be required in the next few years. However, many present-day catalytic reformers were built to operate at higher pressures (up to 600 psig) and at moderate severities, i.e., 96-100 Research octane number at 3 ml TEL per gallon. In order to operate these units at higher severities at design feed intakes, the yield loss would be very costly or, alternatively, substantial revisions and additions would be required to permit operation at the lower pressures (which entail lower yield losses) without substantial reduction in feed intake. In this situation, operation of the reformer at lower severity, together with extraction of the low severity reformate, could well prove economically attractive.

Pilot Plant Studies. The extraction of reformate has been studied extensively. The principal feedstock for these studies was a debutanized 96 leaded Research octane number reformate from predominantly West Texas heavy naphtha having properties shown in Table 3. This feed contained 2 weight percent naphthalene which is difficult to strip from the solvent. Both DEG and sulfolane were used as solvents in extracting this reformate to determine optimum conditions required for each to produce extracts having leaded Research octane numbers (Wiese scale) in the range 104-107.

The 3.5-bpd pilot plant was an integrated unit consisting of a 2.4-inch ID x 8-foot rotating disc contactor with various injector ports for accomplishing extraction and backwashing, a flash chamber for generating backwash, and an extract stripping column together with the

TABLE 3—Composition and Properties of Reformate from Pilot Plant Studies

Carbon No.	WEIGHT PERCENT Saturates	Aromatics	Total
C_5	5.3	....	5.3
C_6	6.4	1.4	7.8
C_7	12.0	13.1	25.1
C_8	11.1	10.7	21.8
C_9	8.2	11.5	19.7
C_{10}	4.9	5.8	10.7
C_{11}	2.1	5.7	7.8
C_{12}	1.4	0.4	1.8
Total	51.4	48.6	100.0

Inspection Data	Total Reformate
Gravity, °API	51.9
RVP, psi	3.6
Research octane, 3 ml TEL/gal	95.7
ASTM distillation, °F	
IBP	142
10%	186
20%	206
50%	250
80%	302
90%	330
EP	396

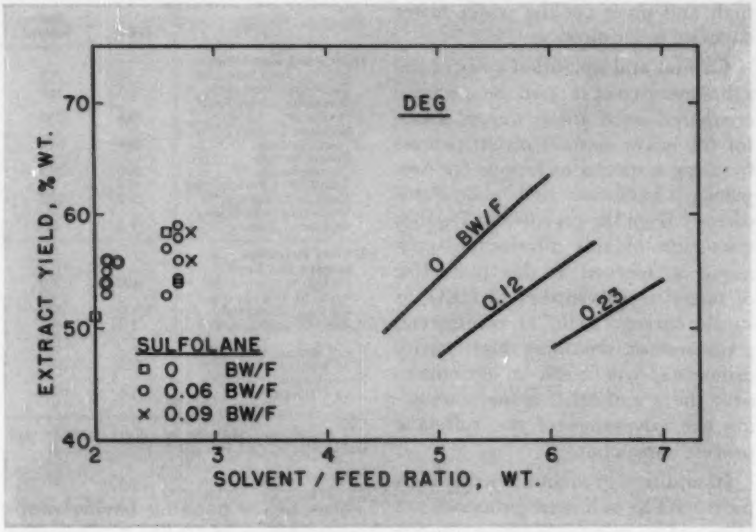

FIGURE 4—At comparable extract yields, the required sulfolane solvent rate is only about 40 percent of that required for diethylene glycol.

necessary heat transfer and auxiliary equipment. Reflux facilities were provided above the stripper to knock back solvent from the extract. For the parallel studies of sulfolane and DEG extractions, temperatures were fixed as being near optimum for each solvent, and are reported in Table 4.

The reboiler stripper pressure was maintained constant at 10 psig for the runs using DEG (fixing the water content of the lean solvent at about 2.8 weight percent). Since this solvent decomposes in the presence of air to form corrosive products, vacuum stripper operation does not appear attractive in a commercial unit. Sulfolane does not suffer this limitation and, furthermore, the extract is more difficult to strip from sulfolane, so stripper-reboiler pressure studies were made over the range 6.6-24.7 psia.

The interrelationship between solvent/feed ratio, backwash/feed ratio (BW/F), extract yields, and extract octane numbers for the two solvents, in each case for lean solvent hydrocarbon contents less than 2 weight percent are shown in Figures 4 and 5. Smooth curves were drawn for DEG in each figure and points are shown for sulfolane. The latter scatter somewhat because of the variation in stripper pressure and percent water in the sulfolane.

The data indicate that at comparable extract yields the required sulfolane solvent rate is only about 40 percent of that required for DEG and the extract octane numbers are somewhat higher. The latter, in part, may be due to higher tray efficiencies for extraction with sulfolane.

A typical raffinate from the pilot plant studies is shown in Table 5. The C_5 and C_6 portion of this raffinate can be recovered as a motor gasoline blending component having a 95+ Research octane number at 3 ml TEL/gal. The remainder can be blended with heavier straight run components for JP-4 jet fuel.

TABLE 4
Optimum Operating Temperatures

Location	TEMP., °F	
	DEG	Sulfolane
Lean solvent inlet	375	260
Reformate feed inlet	230	230
Backwash inlet	250	150
Stripping column reboiler	375	375

TABLE 5—Typical Raffinate Properties

ASTM Distillation, °F	
ASTM Distillation, °F	
10%	168
20%	188
50%	236
90%	338
EP	416
Residue, %v	1
Loss, %v	2
Freezing point, °F	<—80
RVP, psi	4.2
Aromatics, %v	8.5
Bromine No.	1
Total Sulfur, %w	0.01
Mercaptan sulfur, %w	nil
Existent gum, mg/dl	6
Potential gum, mg/dl	9
Aniline-gravity product	9,700
Gravity, API	65.7
Smoke volatility index	79.5
Copper strip corrosion	1A
Flash point, °F	<48

Process Design. Figure 6 shows the flow scheme developed from the experimental studies for sulfolane extraction of the debutanized reformate having properties similar to those studied experimentally to pro-

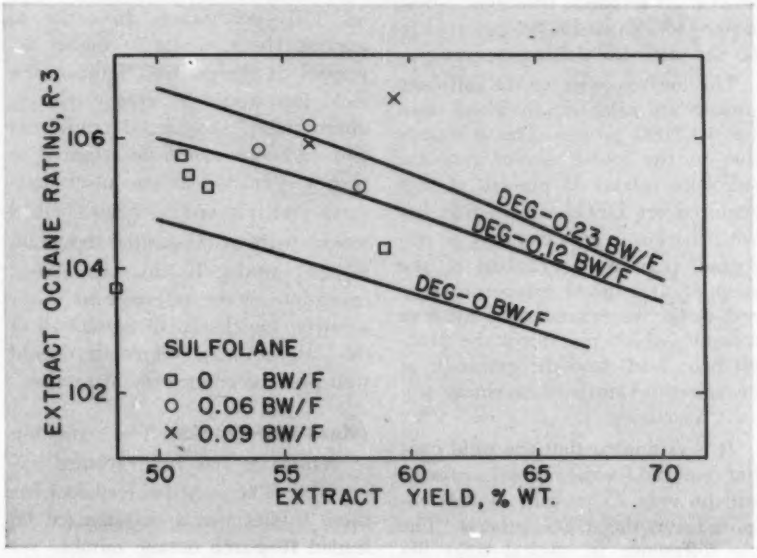

FIGURE 5—Octane ratings are higher when sulfolane is used as a solvent.

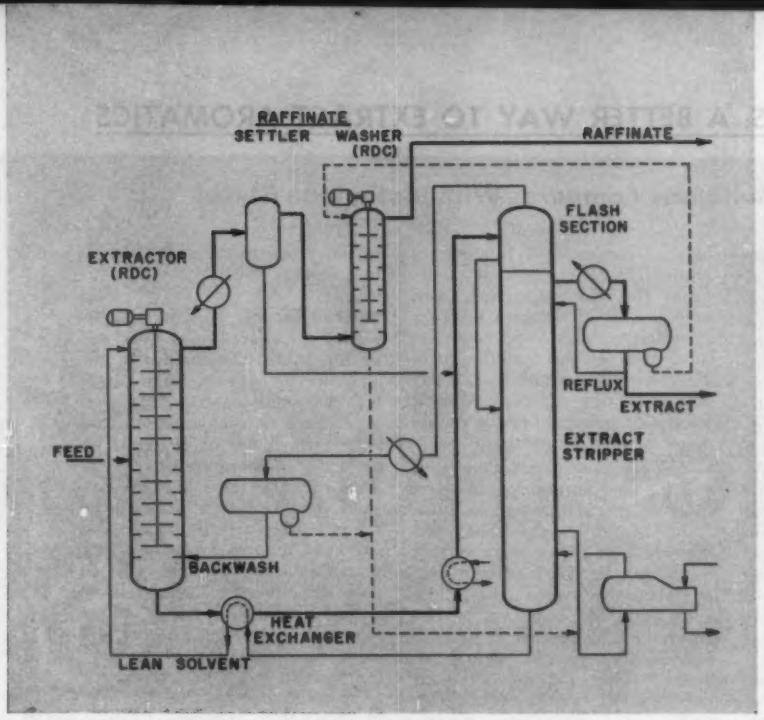

FIGURE 6—Sulfolane extraction of reformate is one way to increase the octane level of your premium grade motor gasoline.

duce an extract (80 weight percent aromatics) having a Research octane rating of 105.4 (Wiese scale) at 3 ml TEL/gal and 54.4 weight percent yield.

Stabilized reformate is fed to two parallel rotating disc contactors. Each contactor has four sections: a top settler, an extraction section, a backwash section, and a bottom settler. Feed enters between the extraction and backwash sections and countercurrently contacts the sulfolane which contains a small amount of water. Below the feed, hydrocarbon backwash reduces the saturate content of the fat solvent. The three entering streams of feed, lean solvent, and backwash distribute between the raffinate and fat solvent.

The fat solvent is heated by exchange with lean solvent and flashed. The overhead is condensed with two phases resulting. The water-sulfolane phase is charged to the process water surge drum. The hydrocarbon phase comprises the backwash to the RDC's.

The liquid from the backwash flasher is heated and charged at subatmospheric pressure to the stripper. Steam generated in the reboiler strips hydrocarbon from the solvent, and hydrocarbon reflux removes sulfolane from the overhead vapors. The overhead vapors are condensed and two phases separate in the extract accumulator where vacuum is maintained with a single-stage ejector. The hydrocarbon phase, which contains less than 50 ppm sulfolane, is split between the above-mentioned reflux and net extract product. The water phase is used to wash the raffinate.

Before being washed, the raffinate is cooled and passed through the raffinate settler to recover a portion of the dissolved solvent and any solvent which might be entrained overhead. The subsequent raffinate wash is accomplished in a rotating disc contactor. The raffinate wash water flows to the process water surge drum from which it is injected into the stripper reboiler to generate stripping steam.

The lean solvent from the stripper is cooled before return to the extraction section. A slip stream of lean solvent goes to the solvent cleanup system where it is regenerated in a vacuum column and returned to the extraction system.

A small amount of ammonia is injected into the system at the stripper reboiler to control pH.

A comparative design was made using DEG as solvent for the same feedstock and extract yield and octane quality. The general flow scheme is the same as described above with the following exceptions:

- The lean solvent from the stripper is not cooled. Because of the higher solvent rate required for DEG, this cooling would not be economical.
- The stripper is operated at slightly above atmospheric pressure to avoid the possibility of solvent deterioration and corrosion due to air leakage into the system.
- Less equipment is required to reject solvent from the raffinate and extract phase since DEG is easier to remove by water washing.
- The extract is recovered from the stripper as two fractions: a light tops and a heavy extract pan cut (which was water washed to remove DEG).

Process equipment for each solvent is designed to handle a feed containing 59 weight percent aromatics, if required. For this feed of higher aromaticity, the extract yield would increase to 61 weight percent and the leaded octane number of the extract would be about 106.5.

Table 6 compares principal operating conditions, utility requirements, and relative capital costs for the two processes.

TABLE 6—Comparison of DEG and Sulfolane for Octane Improvement

	DEG	Sulfolane
Operating Conditions		
Solvent/feed ratio, wt	5.5	2.1
Backwash/feed ratio, wt	0.07	0.07
Stripper reboiler temperature, °F	375	375
Stripper reboiler pressure, psia	24.7	6.6
Lean solvent temperature, °F	375	260
Extractor pressure, psig	225	100
Water content of lean solvent, % wt	2.3	0.6
Utility Requirements/bbl Feed		
Fuel, M Btu	124	113
Cooling water, gal	480	430
Steam, lb	2.5	1.1
Electric power, kwh	0.8	0.4
Total Process Heat Duty, M Btu/bbl feed	84	78
Total Capital Cost* relative to DEG process	1.0	0.85

* Includes the cost of offsite facilities and utilities based on 17,000 bbl/sd feed.

The utility requirements are about 10 percent greater for the DEG process. Sulfolane losses should be lower than DEG losses because of the lower solvent circulation rate and lower average temperature in the sulfolane process and because sulfolane is more stable to heat and oxidation and less volatile than DEG. It is however, a more expensive solvent.

For the same standards, it is estimated that the DEG process would

Here's How Sulfolane Compares With Diethylene Glycol

Solvency-Selectivity Properties. Several comparisons of phase equilibria in sulfolane systems with those in diethylene glycol systems will serve to illustrate the solvency-selectivity properties of sulfolane and their relation to those of other practical extraction solvents. Liquid-liquid phase equilibria in heptane-xylene-solvent systems for anhydrous sulfolane and anhydrous diethylene glycol at temperatures of interest in the respective cases are shown in Figure 1A. In contrast to the diethylene glycol example, sulfolane is completely miscible with the aromatic component and, even at lower temperatures, has greater solvency for both saturate and aromatic components than does diethylene glycol. In addition, the tie lines indicated in the figure show a greater difference in the aromaticities of phases at equilibrium in the sulfolane case than in the diethylene glycol case. Indeed, over most of the range of saturate-aromatic concentrations, selectivity factors (aromatic in extract/aromatic in raffinate ÷ saturate in extract/saturate in raffinate) for sulfolane are substantially greater than for diethylene glycol. Higher molecular weight polyethylene glycols show somewhat higher solvency than DEG; at the same time somewhat lower selectivities. DEG-H_2O systems have somewhat higher selectivity than anydrous DEG but considerably lower solvency for hydrocarbons.

More direct comparisons of selectivities (in heptane-xylene-solvent systems) are shown in Figure 2A. It shows the selectivity factors which correspond to equilibrium pairs of points along the binodal curves as a function of aromaticity in the solvent phase. From this it is apparent, first, that in spite of the high solvency of sulfolane (at a lower temperature) this solvent provides strikingly high selectivities, and second, that this superior inherent selectivity persists into the immediate vicinity of the plait point.

The occurrence of a plait point and the concomitant loss in selectivity within the system as illustrated here impose a limit upon the aromatic purity of an extract which can be obtained in a simple, straightforward extraction. This limit can, however, be circumvented by several artifices if very highly aromatic extracts are desired. Thus, for instance, relatively small amounts of high molecular weight saturate materials may be added to the system (i.e., heavy countersolvent). The result is in effect a reduction of the total aromaticity in the system and a displacement of the selectivity curve shown in Figure 2A to the right as indicated.

Selectivity for aromatics over saturates in sulfolane systems is somewhat less sensitive to molecular weight differences between saturate and aromatic components than in diethylene glycol systems. This effect, which portends a relatively high overall selectivity for broad fractions is illustrated in Figure 3A. Here, selectivity factors for the separation of a straight chain paraffin and an alkylbenzene are plotted as a function of the difference in carbon numbers of the two types for an idealized limiting case in which the materials are distributed at infinite dilution between immiscible heptane and solvent phases. Differences are somewhat smaller in the practical cases, but the effect persists.

Water Effect. In sulfolane, selectivity for aromatics over saturates is fairly insensitive to the addition of water, particularly for the small (0-5 weight percent basis solvent) amounts of water which are of practical interest. Accompanying this invariance of selectivity, there is a small loss in solvency produced upon addition of water. For example, adding 2.5 weight percent water to sulfolane will reduce the solubility (at 212° F) of a 50-50 mixture of xylene-heptane by about 10 percent, but will leave the aromatic-saturate selectivity unchanged in comparison to the anhydrous sulfolane case.

With DEG, however, addition of water enhances the selectivity somewhat, but it also drastically reduces the solvency. For example, addition of 5 weight percent water to DEG (at 302° F) will enhance the selectivity of the same mixture of xylene-heptane by about 25 percent, but will also reduce its solubility in this solvent by almost a factor of two in comparison to the anhydrous DEG case.

Volatility Properties. Limiting relative volatilities, n-alkylbenzenes/solvent, in the respective systems are shown in Figure 4A. In the first limiting case (the upper curves), which corresponds to the bottom of a fat solvent stripper, relative volatilities are slightly higher with diethylene glycol than with sulfolane. This arises, in spite of a higher vapor pressure for the pure diethylene glycol, as a result of the greater deviations from Raoult's Law in

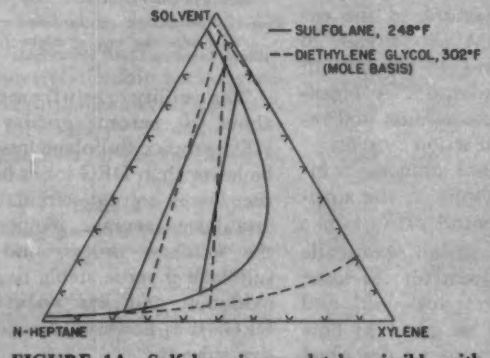

FIGURE 1A—Sulfolane is completely miscible with the aromatic component.

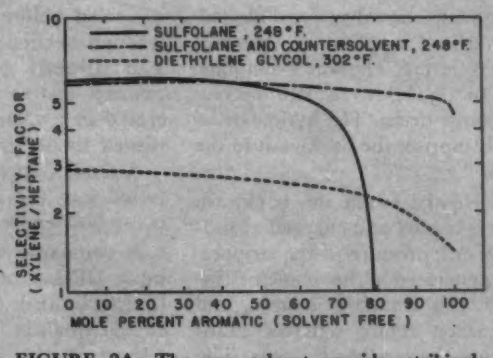

FIGURE 2A—The new solvent provides strikingly high selectivities.

TABLE 1A—Physical Properties of Anhydrous Solvents

	Sulfolane	Diethylene Glycol
Vapor pressure, mm Hg		
302°F	14.5	29
392°F	85.2	192
473°F	.....	760
549°F	760.0	.....
Freezing point, °F	82*	17.6
Refractive index	1.481	1.447
	86°F	68°F
Specific Gravity		
86°F	1.261	1.11
212°F	1.201	.....
392°F	1.116	.....
Viscosity, centipoises		
86°F	10.3	27
212°F	2.5	2.5
392°F	0.97	.....
Heat of Vaporization, Btu/lb mole		
212°F	27,000	28,400
392°F	26,500	.....
Heat Capacity, Btu/lb/°F		
86°F	0.32	0.57
212°F	0.35	0.65
392°F	0.40	0.77
Interfacial Tensions,† dynes/cm		
122°F	3.7	9.5
248°F	2.0	8.5

* 1.3% wt, water reduces the freezing point to 63°F.

† Solvent + 2% wt H_2O; raffinate ex reformate.

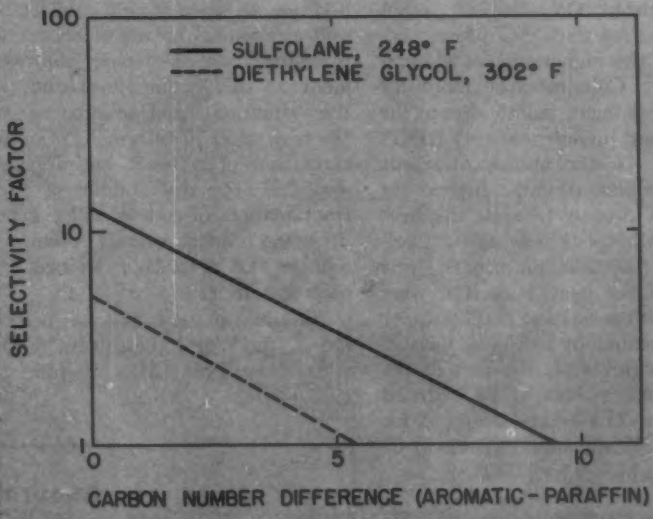

FIGURE 3A—Selectivity of aromatics by sulfolane is less sensitive to the molecular weight difference between saturate and aromatic components.

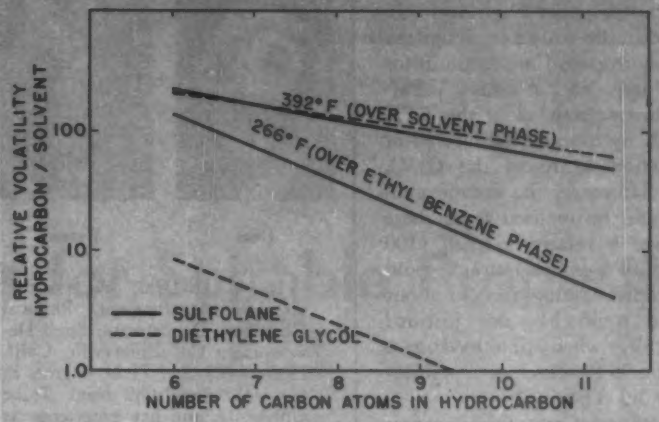

FIGURE 4A—Here are the relative volatilities which occur at the bottom and the top of the stripping column.

alkylbenzene-diethylene glycol systems.

In the second limiting case, which corresponds to the top of a rectifying section of fat solvent stripping column, the relative volatilities are much higher with sulfolane. Here the lesser deviation from Raoult's Law of sulfolane in aromatics and its lower vapor pressure results in a lower partial pressure and a higher relative-volatility.

In further connection with the cleanup of product streams, the distribution of sulfolane from hydrocarbon to an aqueous phase is somewhat less favorable than is that of diethylene glycol. Sulfolane may, however, be water washed from hydrocarbons. Limiting solvent distribution ratios from C_8 aromatic to water (weight basis) are about 8 and 80 in the respective solvent cases; from C_8 paraffin to water, about 210 and 2,400, respectively.

Miscellaneous Physical Properties. A comparison of miscellaneous physical properties with the corresponding properties of diethylene glycol is shown in Table 1A. It is noteworthy that the heat capacity of sulfolane is only about one-half that of diethylene glycol. As is apparent, specific gravity, viscosity, and interfacial tensions are within the ranges which make for high efficiency in extraction equipment. The melting point of sulfolane is considerably higher than that of DEG, although it is reduced substantially by the addition of small amounts of water.

Stability and Corrosivity. At 392° F sulfolane decomposes thermally at a rate of about 0.002 percent per hour to produce sulfur dioxide and unsaturated, probably polymeric, material which induces a brownish color to the otherwise water white material. This decomposition is increased somewhat by the presence of air, but not markedly. In the absence of air DEG degrades thermally to produce gaseous products (principally hydrogen) at rates about 1.5 times those of sulfolane. As is well known, however, DEG degrades rapidly in the presence of air to produce acidic products, which in turn catalyze polymerization to higher gylcols. This can be controlled by the continuous addition of a neutralizing agent.

The corrosivity of sulfolane itself or of sulfolane containing small amounts of water and hydrocarbon is negligible at 392° F (about 1 mil/yr) in carbon steel.

cost about 15 percent more total capital than the corresponding sulfolane process. Columns and pumps cost more for the DEG process because of the higher solvent circulation rate. Columns cost more for the DEG process, mainly due to the larger (and higher pressure) RDC's required. Heater and exchanger costs are also slightly higher for the DEG process (despite the heat exchange between lean and fat solvents for the sulfolane process) due to the higher heat load. If it were possible to operate the DEG stripper under vacuum by use of a suitable oxidation inhibitor, the cost of the DEG process could be reduced somewhat. The capital required for offsite facilities and utilities will be somewhat higher for DEG.

Low Severity Reformates. For the lower severity reformate feedstock used in the process design, higher extract purity could have been obtained with the sulfolane design by using a more paraffinic medium for backwashing (e.g., a heavy paraffinic countersolvent as in the BTX design) or by topping the feed prior to extraction to reject the C_5/C_6 fraction. However, the octane gain which could be realized from these alternatives is relatively small (100 percent pure aromatic extract would have a leaded octane rating of about 110) and probably not justified economically when processing a feed rating 96 Research octane numbers at 3 ml TEL/gal.

Some refineries may find it necessary to bottom their reformate to control gasoline endpoint specifications. Such bottoming would generally reject bicyclics from the feed to extraction and would make extract stripping easier. However, deeper bottoming of low severity reformate to produce a light feed to extraction and a heavy reformate for gasoline blending does not appear desirable because of the relatively large amount of low octane saturates in the heavier portion of the reformate (Table 3).

High Severity Reformates. By the mid-1960's premium gasoline octane numbers may be as high as 104-108. Meeting this requirement will tax refinery facilities even if reforming severities are increased to a leaded octane of 105. Extraction should become an increasingly important and economical means of obtaining premium gasoline octane improvement at this octane level and, in this situation, prefractionation of the high severity reformate prior to extraction of a heart cut appears desirable. The desirabilities of prefractionation, of course, will depend upon the refiner's overall processing scheme and must be examined for each specific case.

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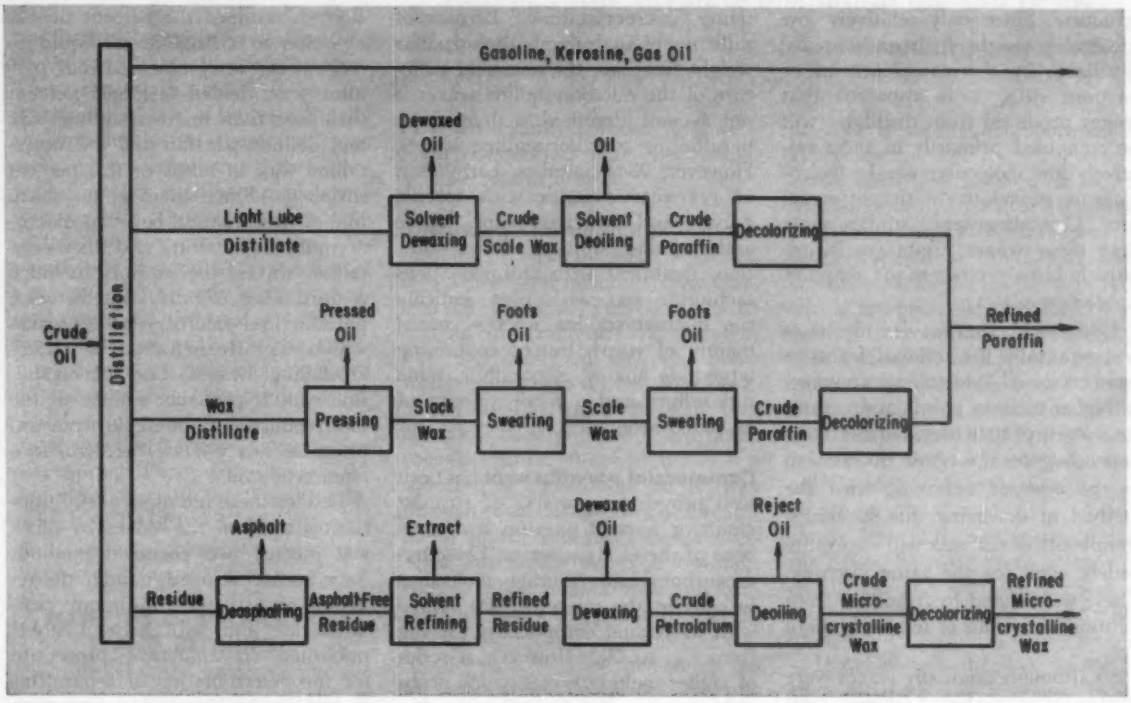

FIGURE 1—The production of wax from crude oil may be divided into a few main operations.

Refine Waxes for Suitable Properties

The growth of the microcrystalline wax industry is due in part to the continuing improvement of wax properties. Here is an up-to-date review of the wax side of our industry

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THE RAPID, almost dramatic, growth of the microcrystalline wax industry is due to the rapid growth of the packaging industry. The appearance of steadily improved microcrystalline waxes permits the paper industry to produce steadily improved packaging materials. In turn, the increasing demands for specialty papers by the paper and packaging industries challenged the ingenuity of the wax producers to make better and more diversified waxes. The surface has only been scratched. Without a doubt the packaging industry and particularly the prepackaged food industry will grow at an increased rate putting more and more pressure on the paper and wax industries.

Here is a review of where waxes stand today.

Structure and composition of wax. Since microcrystalline wax is a derivative of crude petroleum as is also paraffin wax, we must know something of the composition of the crude petroleum to understand that of the waxes; and we must know something about paraffin wax in order to understand microcrystalline wax.

Besides consisting of different types of hydrocarbons, crude oil contains homologous series of these types. Thus low melting, low viscosity waxes have relatively low molecular weights and consist of hydrocarbons of reasonably simple

structure. Since only relatively low molecular weight hydrocarbons are distillable by the usual steam or vacuum stills, it is apparent that waxes produced from distillates will be composed primarily of these relatively low molecular weight hydrocarbons of relatively simple structure. Crystallographic studies show that these waxes crystallize in relatively large crystals in the shape of needles or plates.

Conversely, the heavier distillates and especially the residual fractions from crude oil tend to contain waxes of higher melting points and greater complexity of structure. Furthermore, depending on the crude oil, as well as the type of refining and the method of dewaxing, the structural complexity of the wax will vary quite widely even for the same viscosity. These waxes tend to crystallize from solution in crystals of relatively small size.

So although originally waxes were grouped into two broad classes—crystalline and amorphous—actually, all waxes are crystalline. The low molecular weight distillate waxes merely form crystals of greater size than do the higher molecular weight (residual) waxes.

It was recognized early that waxes produced by pressing non-viscous petroleum distillates were predominantly composed of straight chain or normal paraffins,[1-5] and that differences in crystal size and shape depended on the type and degree of refining and presence or absence of impurities.

Padgett, Hefley and Henrikson[3] found the wax crystals from residual stocks were small even after purification and repeated crystallization from acetone. Quite some time earlier Marcusson and Schlutter[6] had shown ceresine wax (which is hard and dry) is the same as the amorphous wax of petrolatum, refuting the then generally accepted theory that amorphous waxes are soft and plastic. They also tried to prove that so-called amorphous waxes obtained from residual stocks consist mainly of branched chain hydrocarbons—isoparaffins.

In any event, the term "amorphous" has been abandoned and residual waxes are now known by the name "microcrystalline." Because of difficulty of analyzing high molecular weight fractions, the chemical structure of the microcrystalline waxes is not as well identified as that of the paraffin or macrocrystalline waxes. However, X-ray studies, correlation of refractive index with specific gravity and melting point, iodine and bromine addition and substitution, treatment with antimony pentachloride and with urea indicate the microcrystalline waxes consist mainly of naphthenes containing large side chains, isoparaffins, some n-paraffins, and a small amount of alkylated aromatics.

Commercial paraffin wax has been well proven to consist of straight chain or normal paraffin hydrocarbons of the C_nH_{2n+2} series. These hydrocarbons have average molecular weights in the range of 360 to 420 with individual components varying from C_{20} to C_{30}. However, a series of higher melting waxes which probably consist of n-paraffins having molecular weights up to 600 are being produced.

Microcrystalline waxes are primarily alkylated naphthenes and isoparaffins having average molecular weights in the range of 580 to 700, although in some cases the molecular weight may be as high as 900 Individual components vary from C_{30} to C_{60}.

The difference between paraffin and microcrystalline wax is not readily determined by chemical means; and the size of the wax crystal is often very difficult to determine. Thus, various attempts were made to define these two types of wax or at least to distinguish between them by some simple test.

Attempts to differentiate between the two classes of waxes by correlating wax composition and physical properties such as melting point, viscosity, refractive index, surface tension, etc., were the subject of several investigations.[7-11]

Kinsel and Phillips[12] defined paraffin and microcrystalline wax by their Crystallinity Index. They measured the percent shrinkage of waxes around their melting points and by correcting for the thermal contraction, determined the percent shrinkage due to change from liquid to solid state. They observed that paraffin wax yielded a larger percent shrinkage than microcrystalline wax and defined paraffin and microcrystalline wax in terms of this percent shrinkage. Since there is no sharp line of demarkation between macrocrystalline (paraffin) and microcrystalline waxes, the authors included a third class of wax lying between paraffin and microcrystalline waxes which they designated as "semicrystalline" waxes. The semicrystalline wax is probably similar to the intermediate wax obtained from unpressable heavy distillate fractions from crude oil.

Besides these attempts at differentiating between the waxes by physical means, two chemical methods have been developed, namely the reaction of wax with antimony pentachloride and with urea. Leithe[13] published an analytical procedure for the determination of n-paraffins in gasolines, oils, and paraffin waxes which was based on the reactivity of antimony pentachloride with hydrocarbons other than n-paraffins. Schindler and Kinsel[14] modified this method to make it suitable for the analysis of commercial petroleum waxes.

In 1939 Bengen[15] discovered that urea has the ability to form crystalline complexes or adducts with straight chain aliphatic compounds. His claims were confirmed and expanded by Zimmerschied et al,[16] who stated that unbranched or slightly branched alkanes (paraffins), having at least six carbon atoms, readily form well defined adducts with urea at room temperature. Since then this process has been given considerable study and has been applied to the analysis of commercial petroleum waxes as a means of determining the percentage of n-paraffin and probably slightly branched paraffin therein.

Since these chemical and physical methods distinguish only between n-paraffin and all other hydrocarbons, and since microcrystalline waxes contain anywhere from 20 to 90% urea adductible (hence preominantly n-paraffin) components, these methods can only tentatively establish whether a wax belongs in the paraffin, inter-

mediate or microcrystalline wax class.

In other words, the petroleum industry does not use the words "paraffin" and "microcrystalline" wax to specify the degree of crystallinity or the chemical structure of the wax. These names are used to define the production history of the wax. Finally the consumers use these names to indicate certain functional properties —they expect each group of waxes to serve certain purposes and to have certain behavior characteristics. Obviously the functional properties of the wax are the only really important ones, and the methods for differentiating or analyzing the structure of wax are only of importance in so far as they help predict functional properties. A joint subcommittee of the Technical Association of Pulp and Paper Industry and the American Society for Testing Materials (TAPPI-ASTM) is now studying the problem of wax nomenclature and identification.

METHODS OF PRODUCTION AND REFINING

Crude oil is the source of paraffin and microcrystalline waxes and so the production of wax is a part of petroleum refining, which in turn may be divided into a few main operations. The main refining steps are shown in Figure 1.

Distillation. The first operation in petroleum refining is the separation or fractionation of the oil by distillation into fractions of different molecular weights. At first the low molecular weight hydrocarbons boil off and these are all liquids. As the molecular weight increases, solid hydrocarbons make their appearance; and when these distillate cuts are dewaxed the resultant wax is paraffin wax. The undistilled portion—the residue—also contains solid and liquid components. When the residue is dewaxed, the resultant wax is microcrystalline wax.

Distillation may be accomplished in a batch still or in a continuous pipe still. Steam or vacuum is used to distill the heavier fractions to avoid cracking. When paraffin base crude oils are distilled, the residue may be dewaxed without prior treatment. However, when mixed base crudes are reduced, the residue is usually deasphaltized before dewaxing. Asphalt base crudes normally do not have enough wax in the residue to warrant its recovery and, therefore, are usually reduced to a very high viscosity so that the residue may be sold as asphalt.

"Although wax sweating operations are still in use, there is a drift over to solvent dewaxing methods."

Dewaxing and deoiling. The wax distillate is usually first separated into a low pour oil and a wax fraction by pressing. This is done by chilling the fraction to a temperature depending on the pour point which the dewaxed oil should have. The chilled slurry of oil and wax crystals is then pumped to hydraulic presses where the chilled oil is squeezed or pressed out of the wax through canvas-covered circular metal plates and rings under pressures up to 500 psi. The resultant wax is called a slack wax and contains normally between 10 and 35 percent oil.

The slack wax is then subjected to a sweating operation. Basically this consists of first allowing the wax to congeal in a vessel containing a perforated bottom and then gradually allowing the wax to warm up. At the lower temperature an oil, called foots oil, drains out of the wax; and as the temperature is raised, the melting point of the oil sweating out gradually increases.

The resultant wax is known as scale wax and has up to 5 percent oil. It may be decolorized by percolation over bauxite or Fullers earth and sold as White Scale Wax, or it may be again sweated to (a) decrease its oil content still more and (b) to fractionate it into waxes of various melting point ranges. The "foots oil" fraction is usually pumped back to the slack wax for reworking. The resultant sweated wax is "crude paraffin wax." This crude wax may be treated with a small amount of sulfuric acid, neutralized, and washed with water. But whether acid treated or not, the crude scale wax is usually treated with bauxite or Fullers earth to decolorize it and at the same time reduce its oil content still further. The resultant "Fully-Refined Paraffin Wax" has an oil content of 0.5 percent maximum, is practically white in color and has practically no odor. Its n-paraffin content as determined by antimony pentachloride or urea is in the neighborhood of 100 percent.

Although this method is still in use, there is a drift over to solvent dewaxing methods. With the heavier distillates such as the Light Lube Distillate of Figure 1, the wax fraction is not-pressable, and solvent dewaxing must be used. The distillate is first dissolved in a solvent such as ethylene dichloride benzol-methyl ethyl ketone, etc., and then chilled to a temperature depending on the pour point desired for the dewaxed oil. The chilled slurry is then pumped through filters, such as a vacuum rotary filter. The resultant wax cake may then be freed from solvent by distillation and sold as scale wax or redissolved in more dewaxing solvent.

If redissolved, the wax solution is then chilled to a temperature depending on the desired melting point of the paraffin wax and is again pumped through the filters. The filter cake is washed with more solvent to leach out any adsorbed oil. The wax cake is then freed from solvent by distillation and the residue, crude paraffin, is converted to fully refined paraffin as described in the preceding paragraphs. The intermediate or semicrystalline waxes are produced in a similar manner.

Microcrystalline wax is produced by chilling in naphtha solution and centrifuging the chilled solution or by solvent dewaxing. The centrifuge process is the older one. Because the precipated microcrystalline wax forms a fluid mass it is capable of being continuously separated from the chilled oil in a centrifuge. When residual stocks are chilled in a naphtha solution, the resultant crystals are smaller than when dewaxing solvents are used. Therefore, when centrifuges are used, solvents which produce small crystals are to be preferred; but when rotary filters are used, then solvents which yield large crystals are essential.

When crude oil residue is used, the same preliminary treatment is employed, regardless of the dewaxing method used. It is first deasphaltized

if it originated from asphalt bearing crude oils, like Mid-Continent type crude. Asphalt removal is accomplished by treatment with small amounts of sulfuric acid, with propane, etc. Pennsylvania crudes, having no asphalt, are, of course, not subjected to this step. The asphalt-free residue is then usually solvent refined (although this step also may be omitted when dealing with Pennsylvania crudes). Solvent refining is used to improve the quality of the lube oil and is based on the selective solubility of some harmful compounds such as aromatic and unsaturated hydrocarbons in certain solvents. These solvents include furfural, phenol, sulfur dioxide, chlorex (B, B′ dichlorodiethyl ether), and others. Finally the stock is partly decolorized with bauxite or Fullers earth. The refined residue is now ready for dewaxing for the primary purpose of producing a low pour oil.

When centrifuging is used, the waxy residue is dissolved in a petroleum fraction, such as naphtha, chilled in the usual manner to a temperature depending on the desired pour point of the dewaxed oil, and the chilled slurry is pumped through continuous supercentrifuges. Centrifuges which operate at about 15,000 rpm are the most popular.

The wax fraction which is a semi-fluid gel-like mass is separated in this way from the oil fraction and is flowed away from the centrifuge by injecting hot water at the outlet nozzle. The oil fraction is distilled to remove the naphtha and the residue is then decolorized by bleaching with activated clay to the required color. The finished dewaxed oil is often known as "Bright Stock."

The wax fraction is also distilled and the resultant residue is known as "crude petrolatum." This material contains in the neighborhood of 50 percent oil and low melting compoments. In order to convert it to microcrystalline wax, the above dewaxing procedure is repeated; but since the object is now to obtain a reasonable oil-free wax, the operation is known as deoiling. The resultant wax is crude microcrystalline wax, and the oil fraction is usually named "reject" or "reject oil."

The production of microcrystalline wax by solvent dewaxing is basically the same as the production of paraffin wax, and is based on the process developed by Wiles.[17] He found that if the stock was dissolved in ethylene dichloride and then chilled, the wax precipitates out in crystals which are sufficiently large and well defined to permit the mass to be filtered without excessively or rapidly plugging the filter cloth. Since then many other solvents have been successfully used, but all have the same function: to precipitate the wax on cooling so that it is filterable and reasonably free from oil. Dewaxing aids may be used to improve the filterability of the precipitated wax.

As with the centrifuging method, the stock being solvent dewaxed is first processed to yield a low pour oil. The resultant wax fraction, crude petrolatum, is redewaxed (deoiled) to produce crude microcrystalline wax and reject oil.

The crude microcrystalline wax from either dewaxing method is usually dark brown in color and is decolorized to the desired color by treatment with activated clay. The finished microcrystalline wax may contain anywhere from 0 to 15 percent oil, its melting point may vary from 130 to 200° F., its needle penetration from less than 5 to 100, and its urea reactible components (n-paraffin or slight branched paraffin) from 20 to 90 percent. These properties depend on the stock deoiled, on the deoiling temperature and concentration, and on the type of deoiling process used.

Waxes are shipped from the refinery in bulk in insulated or steam-coiled tankcars and tank trucks; in fiber drums, rarely in steel drums; and in slabs. The slabs are usually about 10 pounds in weight and are in turn packaged in cartons and in pallets. The cartons usually contain 100 pounds and the pallets 2,000 pounds of wax.

ANALYTICAL PROPERTIES

Microcrystalline wax (or any petroleum wax) is not a pure compound but consists of a great variety of compounds. Since the wax is produced and purchased to perform certain definite functions, it is apparent that functional properties are of greatest importance. Physical properties are important in so far as they predict functional properties, while chemical properties are at present the least important. To understand better the properties of microcrystalline wax, it is perhaps rewarding to compare them with those of paraffin wax. Some of the chemical properties of both are briefly listed in Table 1. The values reported are those usually obtained, but individual waxes may differ quite widely from them, especially in the case of microcrystalline wax.

We note that both waxes have the usual chemical properties of saturated hydrocarbons. Both, are, of course, completely miscible in each other. They are insoluble in water, alcohol or glycerine but are soluble in petroleum fractions, chloroform, carbon tetrachloride, benzene, ethyl ether, carbon disulfide, etc. Solubility in these solvents is a function of the melting point of the wax—the higher the melting point, the lower the solubility of the wax. Chemical properties tell us something about the purity of the wax; but, with the possible exception of oil content and urea reactible content, tell us very little about the suitability of the wax for any specific use.

Some of the average physical properties of the waxes are listed in Table 2.

Melting Point. The melting point is the temperature at which a material in the solid state changes to the liquid state. Although paraffin waxes have a sharply defined melting point, microcrystalline waxes have instead a melting point range and the magnitude of this range depends on the molecular weight range and the structure of the components. Thus the values obtained when testing microcrystalline waxes depend somewhat on the method used. A knowledge of the melting point of the wax is essential to determine the correct temperature for applying the wax and whether it may be satisfactory for the use to which it is intended.

Penetration. The penetration is a measure of the hardness of a wax. The TAPPI-ASTM method measures the depth of penetration of a weighted needle into the wax in a

specified time. Not only does this method serve to control the degree of standardization of the wax, but it is a rough measure of oil content (more precisely the content of hydrocarbons melting below the penetration temperature). Consequently, this method may also be a rough measure of staining and blockinng tendencies, which will be discussed later.

Color. The color of microcrystalline waxes does not indicate the degree of microcrystallinity of the wax, but does, of course, indicate the degree of refining of the crude wax. In theory, microcrystalline waxes should be light in color but in actual practice they are almost invariably darker than commercial paraffin waxes. Although the presence of colored bodies in microcrystalline waxes is not essential for a wax to possess the functional properties of microcrystalline wax, removal of these colored bodies has an effect on some properties. For example, extensive decolorization appears to decrease somewhat the stability to light and heat. On the other hand, odor is normally reduced with decolorization.

Viscosity and flash point. Since microcrystalline waxes are produced from residual products or from heavy distillates, it would be expected that they would have higher flash points and viscosities than commercial paraffin wax. These properties may be used as criteria of standardization and purity. For example, a low flash point coupled with a high viscosity may indicate contamination by small amounts of low boiling components.

Refractive index, specific gravity and carbon residue. These properties are of no great importance to the producer or user of waxes. They will vary with the stock used and the degree of refining to which a wax is subjected. For example, presence of aromatic components will tend to raise the refractive index and specific gravity of a wax. Decolorization will lower all three values, and especially the carbon residue.

TABLE 1—Chemical Properties of Waxes

TYPE	Paraffin	Microcrystalline
Chemical structure	n-paraffin	isoparaffin, naphthene, and n-paraffin
Molecular Weight	360–420	580–700
Oil Content (ASTM D721-56T), %...	0–1	0–15
Urea Reactible, %	100	20–90
Iodine Number, Hanus	Approx. zero	0–10
Light Stability	Fairly good	Depends on color of wax
Thermal Stability	Poor	Ditto
Reactivity with Sulfuric Acid	Low	High
Neutralization No., mg KOH per g. sample	0.2	0.2
Saponification No., mg KOH per g. sample	2.0	2.0

Contraction. This property is, in general, not an important one as it has no functional significance in the major uses of wax, such as laminating and coating. However, for some uses, such as pattern waxes and in the electrical industry, low contraction is desirable.

Adhesion and flexibility. These are two of the most important functional properties of the wax so far as the paper converters are concerned. They are listed in Table 2 because they serve to differentiate between paraffin and microcrystalline wax.

FUNCTIONAL PROPERTIES

The functional properties of petroleum waxes are the most important ones. These properties are actually physical ones, but because of their importance and because many of these properties are not measured by any widely recognized method, they are discussed separately. The properties vary widely with the type of microcrystalline wax and average values cannot be listed.

Adhesion or laminating strength. Many methods are currently in active use for measuring this property. The ASTM-TAPPI have suggested Method T 642 am-54 as a method for measuring the sealing strength of paraffin wax which they plan to extend to microcrystalline waxes. Kinsel and Schindler[18] published a method which measures the force required to delaminate sheets of cellophane after they have been laminated together by a cold lamination technique. The TAPPI method uses a hot lamination procedure with sulfite paper. Values obtained vary greatly depending on the method, the type of paper, and the type of microcrystalline wax. The very high melting, hard waxes have practically zero adhesion or laminating strength. On the other hand, the lower melting, softer waxes may give very high values. Obviously waxes to be used for laminating purposes must have high values.

Water vapor transmission. Probably the main reason why wax is used with paper either as a coating or laminating agent is to lower the water vapor transmission of the paper. The TAPPI-ASTM have developed TAPPI method 448m to measure the water vapor transmission of waxed paper and laminations. Results indicate that all waxes be they paraffin or microcrystalline offer about the same resistance to the passage of water vapor, provided the wax layer is not broken.

Since paraffin waxes are brittle, creasing the waxed paper will crack the wax layer leaving an area of relatively porous paper through which moisture is readily transmitted. Microcrystalline waxes, on the other hand, are usually flexible; and even creasing the waxed paper does not break the wax film. Because practically all waxed papers are creased in actual use (and among waxed papers we include laminations), the water vapor transmission of creased papers is the more significant property. Consequently, moisture vapor transmission depends greatly on the flexibility of the wax used.

Flexibility. Waxes used for dip-coating, inside liners, certain types of laminations, etc. must be flexible even at relatively low temperatures. Since there is no standard test for flexibility, it is measured by a number of different methods. Several are

TABLE 2—Physical Properties of Waxes

TYPE	Paraffin	Microcrystalline
Melting Pt. (ASTM D127-49), °F	120–145	130–200
Needle Penetration at 77°F (ASTM D1321-57T)	10–20	2–50
Color	White	White to black
Viscosity at 210°F, SUS	35–50	50–100
Flash Point (ASTM D92), °F	350–450	450–550
Refractive Index at 200°F	1.42	1.44
Specific Gravity at 200°F	About 0.75	About 0.80
Carbon Residue, Conradson, Percent	About 0	0–1
Contraction from 10°F above to 50°F below Melting Point (ASTM D1168-54T), Percent	13.5–14.5	9–12.5
Adhesion (or laminating strength)	Zero	Usually high
Flexibility at low temperature	Zero	Usually high

based on bending a wax-coated strip of paper around a dowel and observing flacking or cracking of the wax surface. Other methods bend a strip of wax and either measure the angle through which the wax may be bent at a prescribed temperature before breaking, or else measure the lowest temperature at which the wax will bend through a prescribed angle. Kinsel and Schindler[19] have published a method wherein a column of wax is repeately bent through an angle of 90 degrees at low temperature by an automatic apparatus until the wax column breaks. The flexibility is expressed numerically by the number of bendings required before breakage of the wax column.

Generally speaking, the softer, lower melting microcrystalline waxes tend to be more flexible than the harder, higher melting ones.

Staining and bleeding. It is very important that waxes used for laminations do not have a high staining tendency. Staining is caused by the transfer of oil or low melting components from the layer of wax to and through the paper thereby causing spotting. Many methods are in use but none have been accepted as a standard method. Basically they fall into the general methods. One general method measures the number of sheets of thin porous paper stained by a weighted block of wax placed on them at specified temperatures. The other general method (based on the Navy's Exudation Test) follows the same procedure but measures the loss of weight of the wax block.

A somewhat different approach was described by Kinsel and Phillips[20] who measured staining tendency of petrolatums and waxes by permitting drops of the material to fall and solidify on filter paper and measuring the thickness of oil ring soaking the paper around the solidified drop after storing for 24 hours at specified temperatures.

Phillips[21] studied the various factors which influence staining, using a modification of the Navy's Exudation Test. He concluded degree of staining of a wax at any temperature depends mainly on its penetration or hardness at that temperature, and the latter in turn depends on the percent of the wax components melting below the specified temperature. It is, therefore, essential that low melting components in the wax be kept at a minimum if wax staining is to be kept at a minimum.

Blocking. Blocking is defined as the degree of cohesion or adhesion between contiguous layers of similar or dissimilar packaging materials in roll or sheet form which prevents their being satisfactorily and efficiently used. The Blocking Point is defined as the lowest temperature at which waxed papers will stick together sufficiently to injure the surface films and performance properties. This property is more important when dealing with paraffin wax than with microcrystalline wax. TAPPI-ASTM has published Method T 652-sm-57 which measures blocking temperature by use of a temperature gradient plate.

Without a doubt penetration at elevated temperature has a great bearing on blocking. In any event the softer microcrystalline waxes have low blocking temperatures and the high melting hard microcrystalline waxes have high blocking temperatures. Hence staining and blocking may run parallel with penetration at elevated temperatures.

Other functional properties. Many other functional properties are of importance. Some, such as tensile strength, gloss, scuff resistance, are mainly of importance when dealing with paraffin wax which is normally used to coat paper and not for laminations. However, since microcrystalline wax is often added to paraffin wax for use in paper coatings, the effect of this addition on those functional properties are important to know.

General discussion of functional properties. It will be seen from the preceding paragraphs that microwaxes are called upon to accomplish various functions and some of the requirements preclude the presence of other functional properties. Thus low temperature flexibility is incompatible with hardness at high temperature; high adhesion may be incompatible with non-blocking; low application temperature (hence low melting point) is incompatible with high delamination temperature; laminating wax capable of being sealed at low temperature may be incompatible with low staining tendency; etc.

Consequently, the producer of microwax must make some compromises in order to produce a wax having reasonably wide application.

About the Author

Dr. Joseph Phillips has a B.S. degree in chemistry and a Ph.D. degree from the University of Pittsburgh. After receiving his doctorate, he joined L. Sonneborn Sons, Inc., at its Daugherty Refinery Division, Petrolia, Pa., in 1937. Working primarily in research and development with petrolatum and waxes, Dr. Phillips' work also included refinery problems. In 1957 he was made superintendent of the refinery's Wax and Petrolatum Departments, at the same time directing research in those fields. He has authored various papers and patents on waxes and petrolatums.

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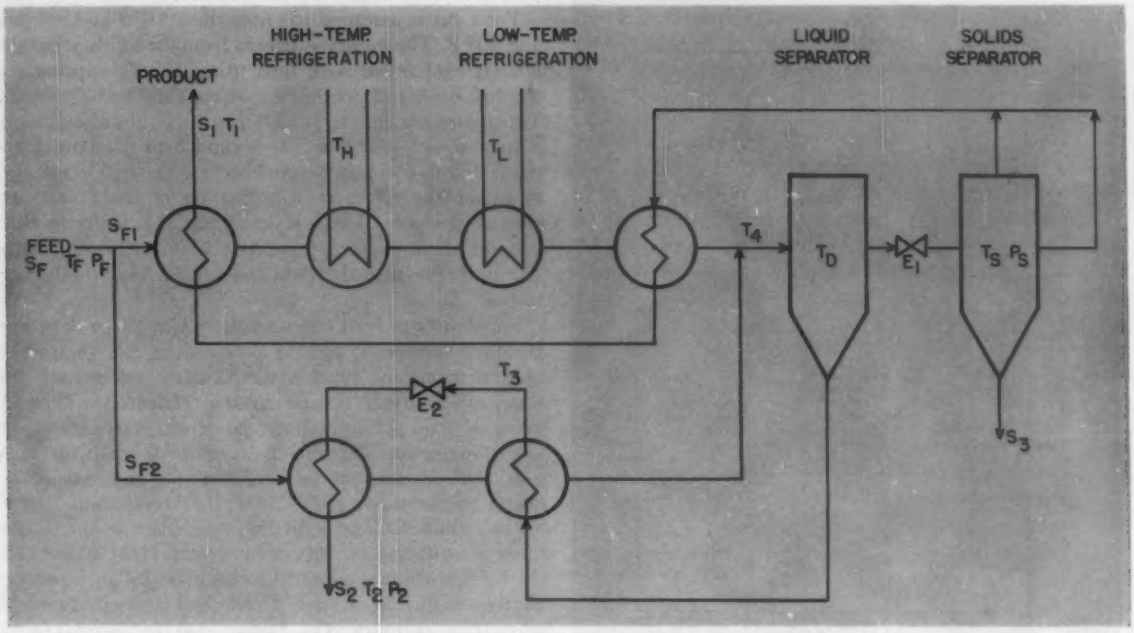

FIGURE 1—Schematic flowsheet for removal of H_2S from natural gas.

From natural gas . . .

Remove H_2S by Freezing

Hydrogen sulfide can be removed economically from natural gas by decantation of the liquid and freezing out of pure solid hydrogen sulfide. The necessary equipment is simple and external power requirements are low

U. K. Im and F. Kurata
University of Kansas, Lawrence

THIS NEW METHOD uses a different approach, for the removal of hydrogen sulfide from natural gas. This method may prove to be more effective and economical. In this method, hydrogen sulfide is removed by decantation of liquid, followed by freezing out of pure solid hydrogen sulfide.

According to the work of Kohn and Kurata[1] on the phase equilibrium of methane-hydrogen sulfide system, a binary mixture forms two stable liquid phases upon condensation at a low temperature. Methane-rich liquid, separated by simple decantation, can be further stripped of its hydrogen sulfide by flashing to a low temperature and pressure in such a way that most of hydrogen sulfide would freeze out substantially as pure solid. In Figure 1 is shown a schematic flow of the process.

Since vapor and liquid, further enriched in the methane, as well as solid phases are present after flashing, the solids separator is under three-phase equilibrium, with only one degree of freedom. Thus, the vapor and liquid compositions are completely fixed by the pressure in the solids separator. Although vapor and liquid phases as separate units depend only on the equilibrium conditions, the composite concentration of vapor-liquid mixture is influenced in the limited range by the liquid conditions prior to flashing. Thus, at a given temperature and a pressure in the liquid separator, the pressure P_s, and accordingly the temperature T_s, is determined by the purity of product desired. The three-phase equilibrium for vapor-liquid-solids system is shown in Figure 2. The vapor and liquid compositions, along with composite composition at two different temperatures of liquid before flashing, are plotted in Figure 3 as functions of the equilibrium temperature.

In the liquid separator, hydrogen sulfide-rich liquid has nearly a constant composition of 89.4 mole percent hydrogen sulfide and 10.6 mole percent methane. The operating temperature of the liquid separator may be varied from —100.1 F. to —130.9 F. The advantage of

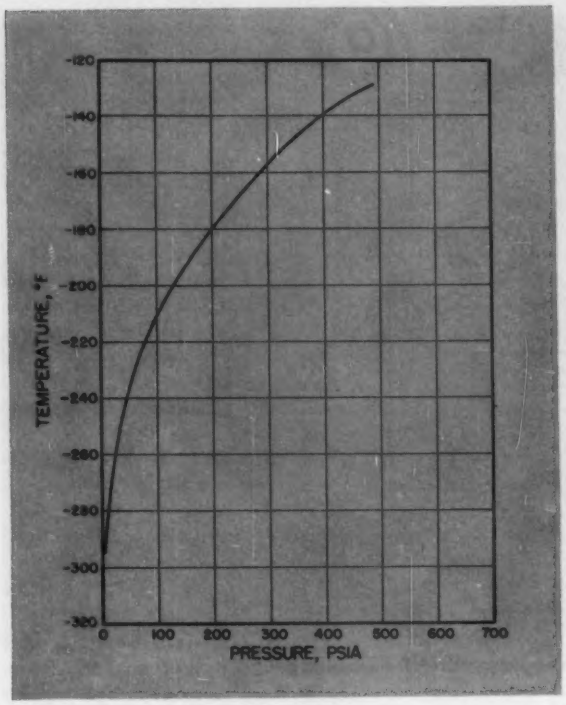

FIGURE 2—Three-phase equilibrium curve for vapor-liquid-solid H_2S-CH_4 system.

one temperature over another is relatively small, mainly due to the small change in the composition of methane-rich liquid with change in temperature.

The solids separator must operate at a pressure below 490 psia and a temperature of —130° F. These are the conditions of quadruple point at which solid hydrogen sulfide begins to form for the first time. Hence, these constitute the upper operating limit. The temperature can be made as low as desired depending upon the purity of product down to —295° F., when the solid methane phase appears.

It is possible to recover the methane in the hydrogen sulfide-rich liquid decanted off in the liquid separator in the same manner as for methane-rich liquid.

At hydrogen sulfide content of feed below approximately 7 mole percent, the mixture does not form two liquid phases. In such a case, the feed gas can be expanded directly through a throttling valve after sufficient cooling to freeze out the hydrogen sulfide.

Preliminary calculations have been made on this method for methane-hydrogen sulfide mixtures of 2, 4, 6, 7, 10, 15, 20, 26, and 32 mole percent hydrogen sulfide. Calculations are based on the production of 100 MM scfd of methane containing 99.8 mole percent methane and 0.2 mole percent hydrogen sulfide. Referring to Figures 2 and 3, the pressure and the temperature in the solids separator must be 30 psia and —252° F. respectively to achieve the purity of the product specified, for an arbitrarily set temperature of 125° F. in the liquid separator. Enthalpy data are from Mathews[3] for methane and from West[2] for H_2S.

Feed gas is assumed to enter the system at 1500 psig and 90° F. The methane stream from the solids separator is heat exchanged with feed using 10° F. approach to the full extent of cooling effect capable by this stream. The hydrogen sulfide stream from the liquid separator is heated to —80° F. in the second heat exchanger and expanded to 300 psia before entering the first exchanger to utilize the effect of vaporization of the stream for cooling purpose. Heat leakage for the system is accounted for by adding 5 percent to the net cooling load required. Pressure drops in the system are wholly neglected.

Since most of feed condensation takes place at a temperature around —100° F., two-stage refrigeration is used with ethane for low-temperature refrigerant and ammonia as high-temperature refrigerant. Thermodynamic data for refrigerants are from Barkelew et. al[4] and Hougen and Watson.[5] Evaporator temperatures are —105° F. for ethane; and —28° F. for ammonia. Condenser temperatures are —20° F. for ethane; and 100° F. for ammonia. Ethane is directly condensed in the evaporator of ammonia refrigeration system. Heat leakage for the refrigeration is assumed to be included in 5 percent allowance for the system. Compressor efficiency of 75 percent is assumed. The horsepower requirements for the refrigeration are minimum values since both methane and hydrogen sulfide streams, exclusive of solid hydrogen sulfide, are exploited to the full cooling capacities for the assumed temperature approach in heat exchangers.

The results of heat and material balance calculations

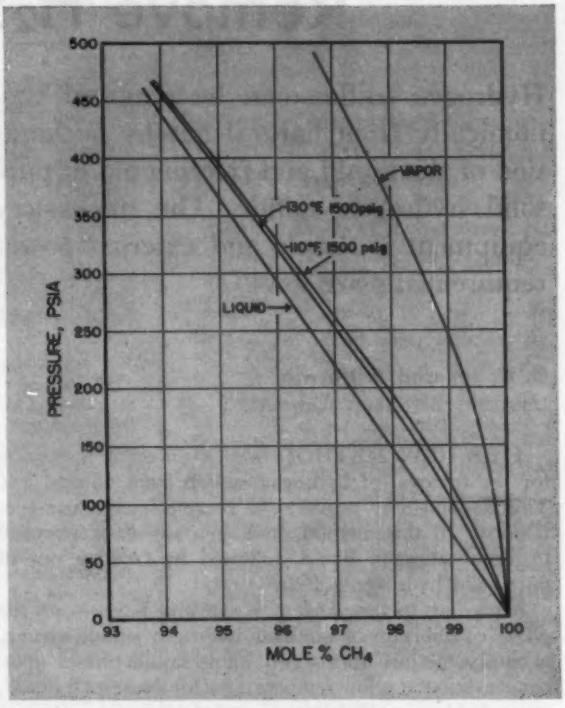

FIGURE 3—Liquid, vapor, and composite compositions vs. the pressure in solids separator.

are tabulated in Tables 1 and 2. The refrigeration horsepower required for the production of 100 MM scfd of methane is plotted against the hydrogen sulfide content of feed in Figure 4.

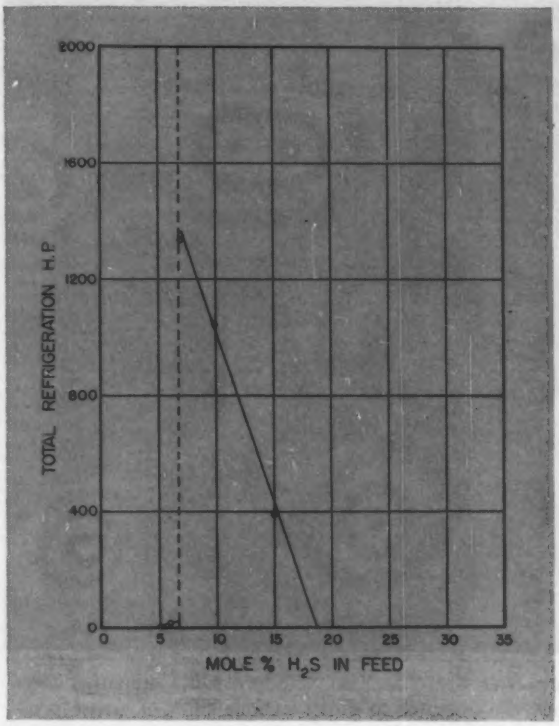

FIGURE 4—Refrigeration load as function of feed composition for 100 MM scfd product.

According to Figure 4, the lower the hydrogen sulfide content in feed, the more horsepower is required for the refrigeration. This is due to the fact that at the lower hydrogen sulfide content the relative amount of hydrogen sulfide from the liquid separator is greatly reduced, thereby reducing the cooling effect performed by this stream. However, for feed content of 7 percent H_2S or less, practically no external refrigeration is required.

With solid hydrogen sulfide thrown in as a coolant, little or no refrigeration will be necessary even for lower hydrogen sulfide content feed. For natural gas containing less than 20 mole percent hydrogen sulfide, an alternative would be to recompress all or part of hydrogen sulfide stream from the heat exchanger and inject it to the feed stream to increase the hydrogen sulfide content so that no refrigeration would be required.

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TABLE 1—Heat and Material Balances for Feed Containing More Than 7 Percent H_2S*

H_2S in Feed Mole %	T_2 °F	S_{F1} MM SCFD	S_{F2} MM SCFD	S_F MM SCFD	S_2 MM SCFD	REFRIGERATION LOAD, HP		
						Low-Tem	Hi-Tem	Total
7	80	107.8	0.2	108.0	0.1	486	846	1332
10	80	103.0	8.6	111.6	4.5	382	666	1048
15	80	97.0	22.5	119.5	12.0	139	243	382
20	79	93.0	35.5	128.5	20.6	0	0	0
26	70	90.0	49.5	139.5	32.5	0	0	0
32	63	88.7	65.6	154.3	47.1	0	0	0

Based on 100 MM acid production of methane containing 99.8 mole percent methane and 0.2 mole percent hydrogen sulfid.
S_2 has a composition of 89.6 mole percent hydrogen sulfide and 10.4 mole percent methane.
S_3 is pure hydrogen sulfide solids.
T_H = —105F.
T_L = —28F.
T_3 = —80F.
P_2 = 300 psia
* **Note in all cases above:** T_F = 90F P_F = 1500 psig.
T_D = —125F P_3 = 30 psig.
T_S = —252F T_1 = 80F.
S_3 = 660,000 lb/day.

TABLE 2—Heat and Material Balances for Feed Containing Less Than 7 Percent H_2S*

H_2S in Feed Mole %	T_1 °F	S_F MM SCFD	S_3 lb/day	REFRIGERATION LOAD, HP.		
				Low-Temp	Hi-Temp	Total
2	39	101.9	164,000	0	0	0
4	63	103.8	352,000	0	0	0
6	80	106.0	551,000	0	16.5	16.5**

Based on 100 MM scfd production of methane containing 99.8 mole percent CH_4 and 0.2 mole percent H_2S.
System does not require liquid separator and hydrogen sulfide heat exchangers.
Liquid in the 3-phase separator formed in the ratio of 1/100 mole to vapor.
S_3 is pure hydrogen sulfide.
** Hi-temp refrigeration only.
* **In all cases above:** T_S = 90F P_F = 1,500 psig.
T_S = —226F P_S = 65 psig.
S_2 = 0 MMscfd.

About the Authors

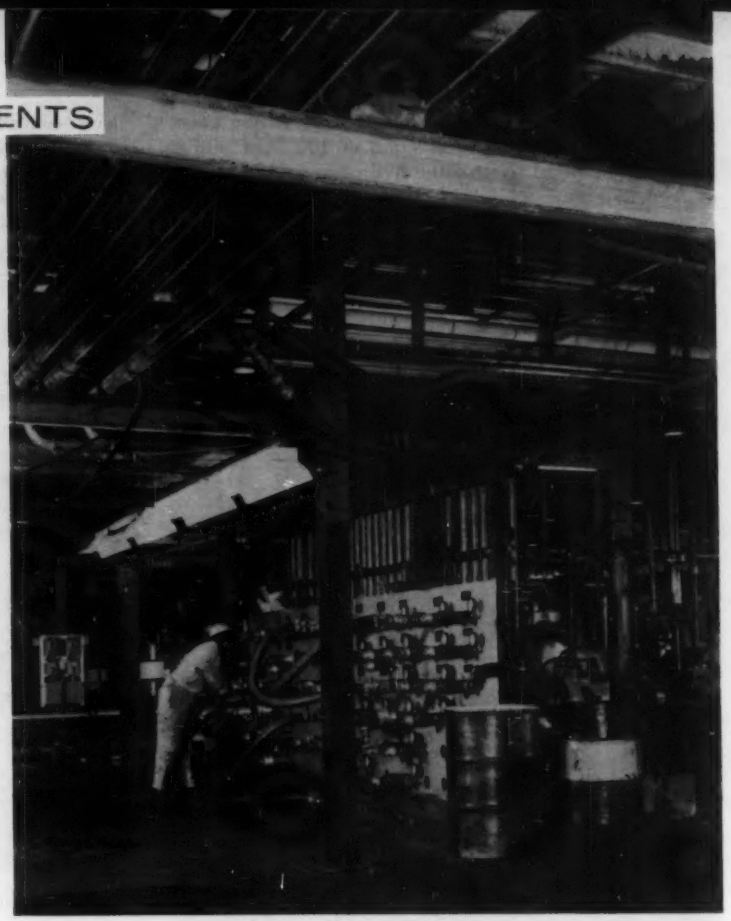
Im Kurata

U. K. Im is a graduate student at the University of Kansas. Holder of a B.S. degree in chemical engineering from the University of Missouri, he was previously with Butler Manufacturing Co. from June, 1957, until January, 1959, when he resigned to devote full-time to work toward a M.S. degree. At Butler Manufacturing, he was a research engineer.

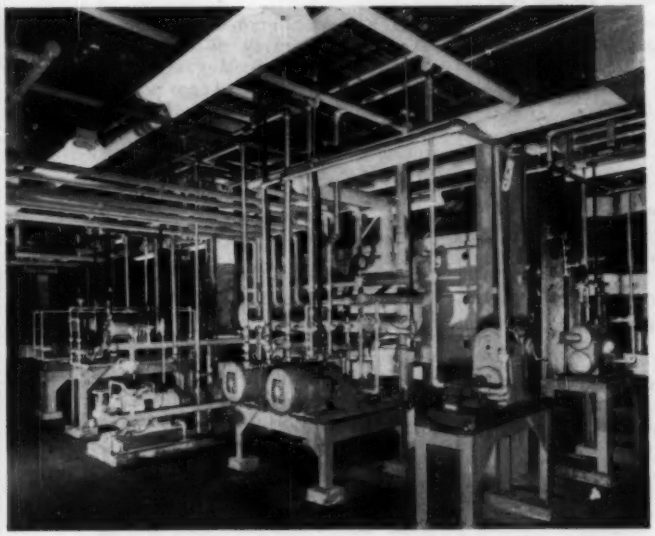
Dr. F. Kurata is a professor of chemical engineering at the University of Kansas, where he engages in teaching, research and consulting. He has a B.S. degree from Case Institute of Technology and M.S. and Ph.D. degrees from the University of Michigan. For the past 11 years he has been doing research and consulting in low temperature phase and volumetric behavior. Dr. Kurata has been a research associate, Engineering Research Institute, University of Michigan; plant engineer, Plasteel Products Co., and chemical engineer, Atlas Powder Co.

Smooth Lines Handle Grease Easily

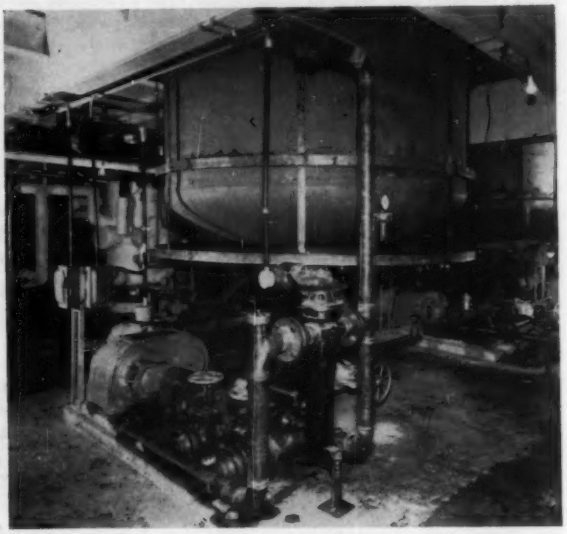
Esso keeps different grades of grease separated during transfer with this system of smooth lines. Neoprene balls are used to pig the lines before changing grades of grease



1. A piping jump-over board at Esso Standard Oil Company's Pittsburgh plant allows the operator to direct various kinds of grease products through production machinery and then to storage tanks or a central container filling area.



2. Since several kinds of grease are routed through the same line, neoprene balls are used to clean out the line and prevent cross-contamination. The pilot plant shown here and the full-scale system were installed by the Blaw-Knox Company.



3. Motor-driven pumps force the grease from the cooking kettles through 3-inch diameter steel pipes to the jump-over board. The modernized system now uses six filling lines where previously 20 separate lines were required.

PROCESS COMPETITOR

ADDITIVES ...A WAY TO PRODUCT QUALITY

Additives are tailor-made chemical compounds. They are added in small amounts to petroleum products to impart new and useful properties not obtained by processing, or to obtain a quality level at lower cost than would be possible by processing.

Additives compete then with refinery processing as a route to better product quality.

In the following articles, additives are viewed with regard to the type and amount used. Each article concerns a class of petroleum products that take advantage of additive's beneficial properties. The products are divided into the following five classes:

- Gasoline
- Other Fuels
- Motor Oils
- Other Lubes
- Other Products

You can now review the recent advances made in additive formulation. Perhaps the use of one or more of them will let you postpone that big capital investment in refinery processing without losing your position in the race for higher quality products.

What Additives Will Do In Gasoline

W. A. Herbst
Esso Research and Engineering Company
Linden, N. J.

ADDITIVES have demonstrated their utility and versatility over the past 40 years in meeting the problems arising from the continuing development of the spark-ignition engine. The additives used in motor fuels (some are also used in aviation gasoline) are of the following types:

- Antiknock agents and scavengers
- Combustion chamber deposit modifiers
- Antirust agents
- Antioxidants
- Metal deactivators
- Fuel induction system cleanliness agents
- Carburetor anti-icing agents
- Dyes

The additive market will, of course, be influenced strongly by the demand for motor and aviation gasoline which is shown in Table 1. The indicated drop in aviation gasoline demand in the future is due to the displacement of the aircraft piston engine by the turbine engine. Turbine fuel additives will not be discussed in this article.

When judging the suitability of an additive, its storage stability,

About the Author

Dr. W. A. Herbst is a research associate for Esso Research & Engineering Co., Linden, N. J., where he is doing special studies on gasoline quality. This includes setting gasoline specifications, forecasting gasoline quality trends and evaluation of new developments affecting the gasoline demand and quality picture. Dr. Herbst has B.S., M.S. and Ph.D. degrees in chemical engineering from Pennsylvania State University.

solubility, and effect on over-all engine performance must also be considered. It is beyond the scope of this paper to discuss these requirements in detail. The pamphlet "Significance of ASTM Tests for Petroleum Products"[4] provides information on methods of measuring these related factors. Information on the performance testing of gasolines has also been published.[5] The following sections then concern specific technical and economic aspects of gasoline additives.

Antiknock Agents and Scavengers. Knock in a gasoline engine results in loss of power and efficiency and causes overheating which, if severe and prolonged, can lead to engine damage such as a burned piston. Gasolines vary in their resistance to knock. Their antiknock quality is expressed as an "Octane Number."

Engines likewise vary in their tendency to produce knock. Their severity is a function of such variables as compression ratio, spark advance, water-jacket temperature, carburetor setting, etc. It is obviously necessary, therefore, that if trouble-free operation is to be obtained gasoline octane level must be matched to engine antiknock requirements.

Engine compression ratios have been increased over the years so that they now have a weighted average of about 9 for 1959. Some models have compression ratios as high as 10.5. This increase was only possible because of an improvement in gasoline Research Octane Number to the current level for premium gasolines of 98 with some current super-premium brands rating about 102.

Early investigators of the knock problem found that adding small amounts of certain materials to the gasoline could greatly reduce its tendency to knock. These included such things as iodine, aniline and volatile compounds of phosphorus, arsenic and a wide range of metallic materials. A series of patents issued to Thomas Midgley, Jr., in 1926 disclose the use of volatile compounds of selenium, tellurium, arsenic, antimony, phosphorus, cadmium, bismuth, titanium, tin, and lead. Over the years a large patent art has been built up in which antiknock activity has been attributed to most of the metals. Other than the compounds of lead and iron which are well known antiknocks, the elements which seem most effective are copper, cobalt, bismuth and tellurium.

Tetraethyl lead meets most of the general requirements for a good antiknock and has been used in gasoline since 1923. When a gasoline containing tetraethyl lead by itself burns in a spark-ignition engine, however, it produces nonvolatile combustion products. Some of this remains behind in the combustion chamber and on spark plugs and ultimately causes malfunctioning of the engine. Tetraethyl lead, therefore, is usually used with a scavenging agent to reduce the amount of deposits formed.

A large amount of study has shown that volatile halides, i.e., ethylene dichloride and ethylene dibromide best combine the various characteristics required of a good scavenger viz deposit reduction, proper volatility, stability, not corrosive to engine parts, low cost, etc. The mechanism of operation of this type of scavenger is to react with the lead in the combustion chamber to form volatile lead halides which are then blown out of the engine through the exhaust. Thus, commercially available tetraethyl lead antiknock fluids are a mixture of tetraethyl lead and scavenging agent.

Of the automotive gasolines sold in 1958, 97.5% contained tetraethyl lead. Because of toxicity considerations, the maximum concentration of tetraethyl lead that is used in automotive gasolines is limited by the U.S. Surgeon General to 3 milliliters per gallon. Actual concentrations are somewhat lower.

An average of about 2.5 ml/gallon was used during 1958 in premium gasolines while regular grades contained about 1.8 ml/gallon. The latter is somewhat low because gasoline supplies have been abundant and it was more economical to raise octane number by processing rather than by increasing TEL concentration. A concentration of 2.2 ml/gallon would appear to be more normal.

Current gasoline sales are split about 33/67 between the premium and regular grades. Thus, the average tetraethyl lead concentration in the U.S. gasoline pool is 2.3 ml/gallon. From these figures and Table 1, the market for tetraethyl lead, ethylene dichloride and ethylene dibromide, in antiknock fluid used in automotive gasoline, is indicated to be as shown in Table 2, assuming the above concentration levels are maintained in the future.

TABLE 1—Trends in U. S. Gasoline Demand

YEAR	U.S. Gasoline Demand, Millions of Bbls.—42 Gals. Each	
	Automotive	Aviation
1958[1]	1331	81.4[a]
1959	1374[b]	.....
1960	1418[b]	60.6[2]
1965	1559[b]	45.3[2]

[a] Demand by grades (ex alkylate).

Grade	Vol. %
115/145	58
108/135	3
100/130	31
91/98	4
Other	4

[b] Assumes 3.2% annual increase [2].
[1, 2, 3] See Literature Cited.

TABLE 2—Market for Tel Antiknock Components in Gasoline

Year	In Automotive Gasoline, Millions of Pounds			
	Automotive Type Fluid	Tetraethyl Lead	Ethylene Dichloride	Ethylene Dibromide
1958	741.3	455.2	139.4	132.7
1959	765.3	469.9	143.9	137.0
1960	789.9	485.0	148.5	141.4
1965	868.4	533.2	163.3	155.4

Year	In Aviation Gasoline, Millions of Pounds		
	Aviation Type Fluid	Tetraethyl Lead	Ethylene Dibromide
1958	93.2	57.2	33.3
1959	...	...	...
1960	69.4	42.6	24.8
1965	51.8	31.8	18.5

At a retail price level of 37.4¢/pound[7] of automotive tetraethyl lead antiknock fluid, it appears that about 277 million dollars is currently being spent by U.S. refiners on motor gasoline antiknock agents. The prices for the scavenging agents alone are currently quoted at 10.25¢/lb. for ethylene

dichloride and 29¢/lb. for ethylene dibromide.

Aviation gasolines also, of course, contain tetraethyl lead. Because of different requirements of the aircraft engine and operating conditions, the composition of the aviation fluid differs from the automotive type in that ethylene dibromide alone is used as a scavenging agent.

The maximum allowable tetraethyl lead content of aviation gasoline[6] is 4.5 milliliters/U.S. gallon for all grades except the 80/87 grade (0.5 ml/U.S. gallon). As indicated in Footnote "a" of Table 1, this grade is included in "others" and is only a small part of the total demand. It is therefore assumed that the average TEL concentration of aviation gasoline in the United States is 4.6 milliliters/gallon. Accordingly, the demand for tetraethyl lead and ethylene dibromide for use in aviation gasoline is calculated to be as shown in Table 2.

At a retail price[7] of 40.9 cents/per pound for aviation tetraethyl lead antiknock fluid, the bill for antiknock agents in aviation gasoline was about $38 million in 1958. This market, however, is a shrinking market due to the predicted drop in aviation gasoline consumption.

Future developments in the antiknock field will probably come from recent interest in coordination compounds of metal carbonyls, for example, manganese (U.S. patent 2,818,417; British Patent 781,065). These compounds are being considered as supplements to, rather than as replacements for, tetraethyl lead. The extent to which they will penetrate the gasoline market remains to be seen. Mercury compounds have also been disclosed as a tetraethyl lead supplement (British Patent 809,319).

The addition of about 0.75 per cent of tertiary butyl acetate as a TEL "appreciator" was recently announced. If the claims made for this material are substantiated and costs are attractive, materials of this type may find growing use in gasoline as octane numbers increase.

Other developments may come about because of engine design trends. As engine compression ratios increase, engine performance problems associated with combustion chamber and spark-plug deposits become more severe. This will intensify interest in agents having lower deposit-forming tendencies.

Combustion Deposit Modifiers. The historical increase in engine compression ratios has given rise, particularly in the past several years, to a number of problems associated with combustion-chamber deposits. Spark-plug fouling resulting in misfiring has already been mentioned. Combustion chamber deposits can also cause too early and/or multiple ignition of the gasoline-air mixture which shows up as "wild ping." "Wild ping" sounds like "knock" except it is a sharper noise and more erratic as to when it appears and disappears.

Under some severe conditions, such as prolonged high speed driving, surface ignition can sometimes quickly cause severe engine damage such as buring holes in pistons. Combustion chamber deposits also cause an undesirable increase in the octane requirements of the engine so that gasolines of higher quality are needed to satisfy the engine after several thousands of miles of operation.

There are no standard laboratory methods for predicting the spark-plug fouling or deposit-ignition characteristics of a gasoline. Extensive road testing in production cars under a variety of conditions is necessary because car design and driving habits markedly influence these phenomena.

It was found several years ago that spark-plug fouling and wild ping could be alleviated by adding to the gasoline low concentrations of certain materials. These materials seem to function by changing the nature of the deposit.

In the case of spark-plug fouling, the mechanism seems to be to change the deposit on the spark plug from one of high conductivity (thus shorting out the plug) to a lower conductivity. The wild ping is probably reduced by reducing the tendency to glow of the carbonaceous materials in the deposit.

One of the earliest materials to be used was phosphorus in the form of tricresylphosphate.[12] Boron compounds have also been claimed to be effective.[13] The partial list of patents shown in Table 3 indicates the variety of these types of materials that have been considered. These include alkyl phosphines, alkyl phosphites, alkyl, aryl, alkyl-aryl phosphates, alkyl-aryl thiophosphites, alkyl-aryl thiophosphates, chloro-alkyl thionophosphates and phospho-sulfurized materials.

TABLE 3—Patents on Gasoline Combustion Deposit Modifiers

Patent	Subject
U.S. 2,405,560	Tributyl phosphite
U.S. 2,427,173	Trimethyl phosphite or phosphate
U.S. 2,724,719	Chloropropyl thiono phosphate
U.S. 2,765,220	Cyclic phosphate
U.S. 2,794,713 to 723 incl.	Phospho-sulfurized materials
U.S. 2,797,153	Trialkyl phosphines
U.S. 2,843,465	Alkaryl thiophosphates or thiophosphites
U.S. 2,862,801	Chloropropyl thiono phosphate
U.S. 2,710,251-2	Alkyl boronic acids and diol esters thereof
U.S. 2,767,069	Cyclic boron compounds
U.S. 2,800,400	Boric acid in polyglycol ethers (UCON) & lower alcohol
U.S. 2,848,312	Borates of glycols

Analyses indicate that about 30 percent of the total gasoline currently marketed on the East Coast contains a phosphorus-type additive. The typical additive content of these gasolines is equivalent to about 20 parts per million (20×10^{-4} Wt.%) of phosphorus.

If it is assumed that all the premium gasolines will ultimately contain a phosphorus additive, the potential market for an agent of this type expressed as pounds of phosphorus is shown in Table 4. Long range both premium and regular grade fuels may contain a combustion control additive. This would result in a market about three times as large as shown. Tricresylphosphate currently[7] costs 32-1/2 cent lb. Some other commercially available additives range from 29 to 36 cents/lb.

TABLE 4—Potential Market for Combustion Deposit Modifiers

YEAR	Phosphorus, Millions of Pounds
1958	2.07[a]
1959	2.16[a]
1960	2.46[b]
1965	2.71[b]

[a] Assumes 30% of all gasoline contains phosphorus.
[b] Assumes all premium gasoline contains phosphorus.

Combustion deposit modifiers are not currently used in aviation gasoline, and there does not seem to be

any strong interest in them for this type service.

To control rumble in high compression ratio engines. There are some indications that higher concentrations of phosphorus may be required in future automotive gasoline. "Rumble" is a dull thudding noise heard in some high compression ratio engines at high engine speeds and loads. As in the case of "wild ping" it is thought to be due to premature (i.e., before the spark) ignition of the gasoline by glowing deposits or hot spots in the combustion chamber. The engine's tendency to rumble increases as compression ratio goes up.

This is a relatively new field and it is being thoroughly investigated by the petroleum and automotive industry. Accordingly, new developments can be expected. These may take the form of improved phosphorus compounds, combination agents to avoid the engine octane requirement increase debit or entirely new additives.

Antirust Agents. Rusting can be a problem in automobile fuel systems and in the tanks, pipe lines, and tankers used to bring the gasoline to the motorist. It is not only costly to the petroleum transportation people but can cause the motorist trouble in the form of leaky gas tanks, plugged gasoline line filters and faulty carburetor operation when a particle lodges in the jets or needle valve. The motorist's requirements have been becoming more severe as carburetor complexity has increased, making them more critical and requiring finer gasoline filters.

Rusting, of course, is promoted by water which can enter the car and/or gasoline transportation and storage systems by condensation or gross contamination. Sea water is particularly harmful and is a constant problem where gasoline is transported by sea.

To help alleviate this situation, many modern gasolines contain an antirust agent. Table 5 illustrates the types of compounds that have been patented. These include unsaturated organic acids, alkyl acid orthophosphates, amine and ammonium sulfonates, fatty acid amines, etc.

In those gasolines containing an antirust agent, the concentration range may be from 1 to 10 pounds of active ingredient per 1,000 barrels of gasoline, depending upon the agent used, degree of protection desired, nature of the gasoline, etc. Assuming a concentration of 3 lbs. active ingredient per 1,000 barrels, the potential market for antirust agents in all motor gasoline is shown in Table 6.

TABLE 5—Partial List of Patents Relating to Gasoline Antirust Agents

Patent	Subject
U.S. 2,533,300-4	Amine mahogany sulfonates
U.S. 2,585,843	Fatty acid partial esters of polyhydroxy alcohols
U.S. 2,594,266	Ammonium mahogany sulfonates
U.S. 2,600,113	Alkyl mercapto acetic acids
U.S. 2,739,050	Ammonium polyalkylated benzene sulfonate
U.S. 2,851,343	Dialkyl acid o-phosphates
U.S. 2,863,742-7	Amine salts of dialkyl acid o-phosphates

TABLE 6—Potential Market for Antirust Agents in Gasoline

YEAR	Active Ingredient, Millions of Pounds	
	Automotive[a]	Aviation[b]
1958	4.0	0.57
1959	4.1	...
1960	4.3	0.42
1965	4.7	0.32

[a] Assumes 3 lb. active ingredient/1000 bbls. gasoline.
[b] Assumes 7 lb. active ingredient/1000 bbls. gasoline.

The actual market at present is lower than these figures since it is known that not all gasolines contain an antirust agent. Information on what part of the automotive gasoline is so treated, however, is not readily available.

Prices for presently available antirust agents may range from 20 to 100 cents/lb. (based on total agent). One agent containing 50% active ingredient sells for 27 cents/lb.

The future of antirust agents in automotive gasoline will be the resultant of a number of diverse trends. Corrosion will always be a problem in bulk tankage, tankers, etc., but it is questionable whether this factor alone would support the continued use of gasoline soluble antirust agents. It is common practice to protect pipe lines against rust, but this may be done either with gasoline soluble or gasoline insoluble (e.g., sodium nitrite aqueous solution) materials.

While automobile carburetors are becoming more critical to suspended solids in the gasoline, there is a trend towards the use of bigger and better fuel line filters and at least one automobile make uses a synthetic gasoline line. Also, there is growing interest in the weight savings possible by using more and more aluminum in automobile construction. This might result in replacing the automobile's present terne-plated steel gasoline tank with an aluminum tank. Where these various factors will balance out is difficult to predict.

There is one point that must be kept in mind in adding antirust agents to gasoline. Some of these agents tend to loosen rust and scale when they first come in contact with a system not previously treated. Thus, their introduction must be slowly and carefully done in order to avoid an epidemic of complaints when they are first introduced.

Antirust agents are also used in aviation gasoline. Military specifications[6] require that "an approved corrosion inhibitor shall be added." Certain corrosion inhibitors have been approved under specification MIL-I-25017 (ASG) and Amendment 1 in concentrations ranging from 4 to 20 pounds (total agent) per 1,000 barrels of gasoline.

Assuming an average concentration of 14 pounds/1,000 gallons and assuming 50 per cent active ingredient, the potential market for antirust agents (active ingredient) in aviation gasoline is also shown in Table 6.

The use of antirust agents in aviation gasoline is currently being reexamined. It is possible their use in such fuels will be discontinued. Future developments in the automotive gasoline antirust field will probably be along the lines of improved and/or more economical materials.

Antioxidants. Most gasolines under normal conditions of storage will form "gum." This is a high boiling, sticky, viscous material which, if in high concentration, may deposit in the automobile tank, fuel lines, carburetor, intake manifold or on in-

take valves and cause malfunctioning of the engine. It is important, therefore, that gum formation in gasoline during storage be kept at a low level. For example, the ASTM Tentative Specification for Gasoline (ASTM D-439-58T) specifies a gum maximum of 5 milligrams per 100 milliliters (as determined by Tentative Method of Test for Existent Gum in Fuels ASTM D-381).

Gum is formed by the oxidation[10] and polymerization of unstable components of the gasoline. The nature and concentration of these deleterious materials varies with the source of the gasoline, i.e., the type of crude and processing it receives. Different gasolines, therefore, can vary widely in storage stability (i.e., rate of gum formation during storage). One method of measuring oxidation stability is by ASTM D 525-55-Oxidation Stability of Gasoline (Induction Period Method). Other methods of evaluation have been described.[11]

While gasoline stability can be improved by various treatments such as caustic washing, acid washing, contacting with absorbent solids such as activated clays, partial hydrogenation, etc., it is frequently more economical to add an antioxidant.

Gasoline antioxidants are available in large numbers under various trade names. The most common active ingredients are:

- 2,-6-di-t-butyl-4-methyl phenol
- N,N¹-di-sec-butyl-p-phenylene diamine
- 2,4-dimethyl-6-t-butyl phenol
- N-butyl-p-aminophenol

The antioxidant may be supplied as a pure material or as a concentrate in solution. Solvents include low molecular weight alcohols or aromatic hydrocarbons such as toluene. Current prices cover a range of about 80 cents to $1.15 per pound of active ingredient.

Antioxidants are relatively nonvolatile and therefore, excessively high concentrations (above about 12-50 pounds active ingredient/1,000 barrels depending on the type) tend to form deposits in the intake manifold of the engine and cause trouble. Normal concentrations are appreciably lower than this. Probably a reasonable average is 5 pounds active ingredient/1,000 barrels. On the basis of these numbers, the antioxidant market in motor gasoline is shown in Table 7. The indications are that the antioxidant bill for automotive gasolines was about 6 to 7 million dollars in 1958.

The first three inhibitors listed before are approved for use in aviation gasolines[6] in an amount not to exceed 8.40 pounds active ingredient per 1,000 barrels. The potential market for antioxidants in aviation gasoline is, therefore, as shown in Table 7. The actual demand is difficult to estimate because of lack of information on the proportion of the aviation gasoline containing inhibitor.

TABLE 7—Market for Antioxidants in Gasoline

YEAR	Active Ingredient, Millions of Pounds	
	Automotive	Aviation
1958	6.66	0.684
1959	6.87	.....
1960	7.09	0.509
1965	7.80	0.381

As the octane quality of premium motor gasolines moves above present levels, it is expected that the concentration of unsaturated hydrocarbons will decrease while the aromatic and paraffinic components will increase. The latter two are more stable than the unsaturates and the concentration of antioxidants required in these grades may decrease somewhat. However, this will probably be more than compensated by the fact that increases in the octane quality of the regular grades will tend to reduce storage stability and thus require higher antioxidant levels in this grade.

Antioxidant requirements of the aviation gasolines are not expected to change appreciably.

Metal Deactivators. A class of compounds closely associated with, and sometimes used in conjunction with, antioxidants is the "metal deactivators." Gum formation is catalyzed by many metals (e.g., copper and iron). These may be dissolved in the gasoline in trace amounts or they may come in contact with the gasoline as gross metal surfaces in tanks, pipe lines and automobile fuel system components. It is possible to considerably reduce the adverse effect of these materials on gum formation by adding to the gasoline metal deactivators.

The following materials are representative of the active ingredient in currently available metal deactivators:

- N,N¹-disalicylidene-1,2-diaminopropane
- N,N¹-disalicylal ethylene diamine
- salicylal-orthoaminophenol

They are usually sold as a concentrate in an aromatic hydrocarbon such as toluene or xylene. Current prices range from about $2.25 to $6 per pound of active ingredient. Approximate dosage is of the order of 1 pound of active ingredient per 1000 barrels of gasoline for the cheaper metal deactivators. Data on the proportion of the gasoline pool treated with metal deactivators are not readily available. However, it is known that not all gasoline is so treated. Thus, the figures shown in Table 8, based on treating the total gasoline pool, are undoubtedly too high. However, they do indicate the order of magnitude of the market.

TABLE 8—Estimated Potential Market for Metal Deactivators in Gasoline

YEAR	Active Ingredient, Millions of Pounds
1958	1.3
1959	1.4
1960	1.4
1965	1.6

Current military specifications do not permit the use of metal deactivators in aviation gasoline.

Fuel Induction System Cleanliness Agents. The fuel induction system is here defined as the carburetor and intake manifold of the engine up to and including the underside of the intake valve. Through these parts pass all the air and gasoline that provide the energy to operate the automobile. During the evolution of the modern automobile, gasoline and lubricant, there have been occasions in the past when troublesome deposits have formed at various points in the system.

Deposits have accumulated on the walls of the carburetor throttle[16] body, in the intake manifold and on the intake valve stem and valve underside. Most of the contaminants enter with the air in the form of crankcase blow-by, exhaust fumes, smoke and dust. Other sources may be nonvolatile components in the gasoline (e.g., dyes, gum, etc.) and poor quality lubricants.

Satisfactory solutions to most of

these problems have evolved so that at present the problem is well under control. The solutions have on different occasions involved modifications in the fuel induction system, the gasoline and the lubricant or a combination of two or three.

One important factor in the present satisfactory situation is the use, by many gasoline manufacturers, of a cleanliness agent in their gasoline. There is no standardized laboratory method of testing the effectiveness of such materials. A reliable evaluation involves extensive engine testing in the laboratory and field.

Table 9 presents a partial list of patents to illustrate the variety of materials proposed as gasoline cleanliness agents. The petroleum neutral oil type (U.S. 2,646,348), present in a number of brands of gasoline, functions by remaining liquid in the intake system and thereby keeping the contaminants in solution or suspension so that they wash through. They also provide supplementary lubrication for the intake valve and assist in lubricating the cylinder walls and piston rings. Some of the others are claimed to be effective because their surface active properties keep the contaminants from adhering to the metal surfaces.

TABLE 9—Some Patents Related to Gasoline Solvent Oils and Cleanliness Agents

Patent	Subject
U.S. 2,469,737....	Polymerized α—β—unsaturated acid esters, or copolymers of vinyl acetate & alkyl fumarate or maleate
U.S. 2,529,496....	Organic silicon compounds, e. g., silicone oil
U.S. 2,646,348....	Petroleum neutral oil & isopropanol
U.S. 2,765,221....	Silicone with aryl phosphate
U.S. 2,800,401....	Partly hydrolyzed vinyl acetate/olefin copolymers
U.S. 2,807,525-6...	Polyglycol ethers (UCON) + lower alcohol
U.S. 2,821,538....	Carbonate diesters of polyglycol ethers and alcohols
U.S. 2,844,448 to 451, incl.....	Carbonate diesters of polyglycol ethers and alcohols
U.S. 2,839,371....	1, 2 substituted imidazoline bicarbonate
U.S. 2,839,372....	Acyclic amino alkylene amide or its bicarbonate
U.S. 2,839,373....	N-aliphatic substituted amino alkylene amide

The variety of materials used as a gasoline cleanliness agent make it difficult to make firm estimates as to the probable sales and value of these materials. The oil type additive is usually used in concentrations up to about 0.5 percent and may cost 50 cents/gallon. The surface active variety is said to be effective in concentrations approximating 12 pounds/1,000 barrels. One such agent is available at a cost of 95 cents/pound.

Fuel induction system cleanliness agents are not used in aviation gasoline.

Carburetor Anti-Icing Agents. The vaporization of gasoline in the carburetor venturi cools the adjacent parts. During the period while the engine is warming up, these parts, under some atmospheric conditions, can become cold enough to condense water from the incoming moist air and form ice in the carburetor. Stalling of the engine during idle (e.g., when stopped at a traffic light) results.[14,15] The most critical conditions are at ambient air temperatures in the range of about 30° to 55° F. and a relative humidity above 60 percent.

To avoid the annoyance of these stalls during warm-up, many modern gasolines contain an anti-icing agent. The only reliable method of evaluating the effectiveness of these agents is by actual tests in typical automobiles.

Two general types of anti-icing agents exist. One may work by dissolving in the water and lowering its freezing point. Examples of this type include alcohols, glycols, formamides, etc. The other is a surface active agent type. It has been suggested that it acts by coating the ice particles and the carburetor walls so that they won't cling together or to the carburetor walls. The amine or ammonia salts of phosphates are examples of this type. A number of patents dealing with carburetor anti-icing agents are listed in Table 10.

TABLE 10—Patents Dealing with Carburetor Anti-Icing Agents

Patent	Subject
U.S. 2,579,692....	Dimethyl carbinol with solvent oil
U.S. 2,701,754....	Branched glycols, e.g., 2-methyl-pentane diol-2, 4
U.S. 2,706,677....	Dimethyl formamide
U.S. 2,857,255....	Glyceryl mono oleate

Isopropyl alcohol (U.S. patent 2,579,692) was the first carburetor anti-icing agent to be used commercially in automotive gasolines. It may be used in concentrations up to several volume percent, depending upon gasoline volatility and the degree of protection desired. Some of the other materials, particularly the surface active agents, are used in much lower concentrations (0.01 to a few tenths of a percent). Some anti-icing agents have been said to be effective in concentrations as low as 0.005 percent.

In view of this great diversity and the lack of accurate information on the degree to which these various materials has penetrated the market, it is not possible to estimate the consumption of the various anti-icing agents.

Isopropyl alcohol is quoted[7] at 42 cents/gallon. Gasoline treating costs will, of course, depend upon the concentration and type of agent used.

There are no indications that the need for an anti-icing agent in gasolines will disappear in the foreseeable future. Accordingly, it may be expected that work will continue actively in this field and that new developments will come along. The nature of these developments is difficult to predict.

Anti-icing agents are not used in aviation gasolines as such. There is some use of alcohol-water injection to suppress detonation during take-off.

Dyes. Gasoline is dyed for a number of reasons. With gasolines containing tetraethyl lead, it is intended, in case of spillage, to warn of the toxic nature of the gasoline. They are also used to impart distinctive colors to different brands and grades. Distinctive colors aid in handling gasolines at bulk plants in characterizing the gasoline grade and thus avoid inadvertent mixing and contamination.

Gasoline dyes are hydrocarbon soluble, organic compounds, usually of the azo and anthraquinone types. The four most commonly used[8] are shown below.

- Yellow—p-dimethylaminoazobenzene
- Orange—benzene-azo-2 naphthol
- Blue—1,4 dialkylamino-anthraquinone
- Red—methyl derivatives of azobenzene-4-azo-2-naphthol

A wide variety of colors has been used in automotive gasolines. These

include red, orange, yellow, blue, bronze, copper, amber, gold, green, purple, etc. Dye concentrations[9] may range from about 0.18 to 2.6 pounds per 1,000 bbls.

If an average concentration of 0.6 pounds/1,000 bbls. is used, the amount of dye required to color all the automotive gasoline is as shown in Table 11. It should be emphasized that these figures are of unknown accuracy and are intended only to indicate the order of magnitude of the market. Accurate figures on dye concentration in automotive gasoline are not readily available.

TABLE 11—Market for Dyes in Gasoline

YEAR	Millions of Pounds	
	Automotive	Aviation
1958	0.80	0.065
1959	0.82	.....
1960	0.85	0.048
1965	0.94	0.036

Aviation gasolines[6] are dyed in accordance with the concentrations shown in Table 12. The weighted average concentration of dye in all aviation gasoline is estimated to be about 0.8 pounds/1,000 bbls. The total aviation market calculated from this average concentration and the demand figures in Table 1 is also shown in Table 11. Future developments in this field directed towards reduced gasoline treating costs and a reduction in tendency to form intake manifold deposits would be most welcome. The latter might be accomplished by increased hue and tinctorial strength (require lower concentrations) or increased volatility.

TABLE 12—Dyes Used in Aviation Gasoline

Aviation Gasoline Grade	Maximum Concentration, Lb. Per 1,000 Bbls.			
	80/87	91/96	100/130	115/145
Color	Red	Blue	Green	Purple
Dye Used				
Blue	0.046	0.528	0.435	0.435
Red	0.802	.....	.....	0.303
Yellow	.....	.....	0.649	.....
Total	0.848	0.528	1.084	0.738

(Originally presented before the Commercial Chemical Development Association at Mount Pocono, Pa., May, 1959.)

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. . . In Other Fuels

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THE USE of additives for fuels other than gasoline has grown from essentially nothing 20 years ago to a position where today additives have a very important role in the preparation of distillate fuels. This growth is shown in Figure 1.

Assuming continued technological development, it is predicted that the increase in demand for additives for these products will continue unabated. Research and development work on additives for aircraft turbine fuels, both commercial and military, appears to be one of the most promising fields of the future.

Fuels other than gasoline fall into the general categories of distillate and residual fuels. The term distillate fuels applies to those liquid petroluem products which are heavier than motor gasoline and, for the most part, lighter than residual fuels. The basic components of residual fuel are crude bottoms and cracked material and they are usually produced in three ASTM grades—Nos. 4, 5 and 6.

Additives for residual fuels are seldom added at the refinery and in many cases are of dubious value. This report then will be confined to distillates. Table 1 shows a tabulation of distillate fuels classified as to their service together with a listing of the general types of additives used in these fuels.

WHAT ADDITIVES ARE USED IN DISTILLATE FUELS

Corrosion Inhibitors. Distillate fuels themselves are not usually cor-

rosive under ordinary storage conditions. During normal distribution and handling of these fuels, however, it is almost impossible to avoid water entrainment. Much of this entrained water is due to condensation of moisture laden air which enters storage facilities with changes in ambient temperature. It is this entrained water in combination with dissolved oxygen which causes rusting of steel surfaces.

Additives are employed in most present day distillate fuels to prevent rusting of those surfaces in contact with the fuel. Rusting of storage facilities poses a serious problem due to the high placement costs. It is also necessary that corrosion be minimized to prevent the entry of rust particles into pumps and metering equipment of burners and engines in order to prevent wear and seizure.

Corrosion inhibitors for distillate fuels are oil-soluble polar compounds which function by coating the steel surfaces with a protective film of mono-molecular thickness. Examples of additives used for the purpose are ammonium mahogany sulfonates and organic phosphorus compounds. Corrosion inhibitors are generally used in concentrations ranging from 3 to 20 pounds per 1000 barrels of fuel.

Oil soluble corrosion inhibitors protect only the surfaces in contact with the oil. Such additives are generally ineffective in preventing corrosion of steel surfaces in contact with the water that has settled to the tank bottom. To protect against corrosion below the oil layer a water soluble inhibitor such as sodium nitrate in combination with an alkaline material is often used. These materials are insoluble in the fuel and thus must be added directly to the storage facility.

Corrosion inhibitors are mandatory for most military gas turbine fuels and are almost universally employed in other distillate fuels.

Standardized laboratory test procedures have been developed for evaluating the effectiveness of corrosion inhibitors. The extent of rusting of a steel specimen is a given period of time under controlled conditions of humidity and temperature is used as a criterion for evaluating the effectiveness of a corrosion inhibitor.

Metal Deactivators. The stability of distillate fuels under severe or long time storage conditions can be markedly affected by the catalytic effect of trace metal contaminants

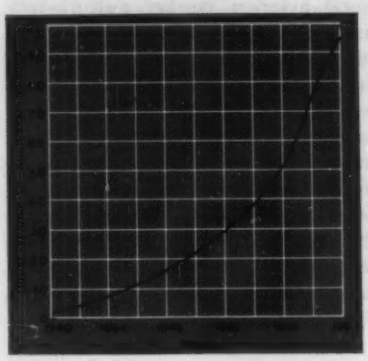

FIGURE 1—Today additives represent a sizable market.

in the fuel. Copper, in particular, greatly accelerates gum and sludge formation in light petroleum products. As little as 0.1 part per million of copper in the fuel is sufficient to cause eventual trouble under adverse storage conditions. Since copper in trace amounts is frequently picked up by distillate fuels in the course of handling, organic metal deactivators have been developed which arrest the deleterious effect of this metal. These additives are effective in concentrations of 0.1 to 2.0 pounds per thousand barrels of fuel. They function by tying up the metal ion in an un-ionized chelate structure, hence their designation as chelating compounds. Typical metal deactivators used are:

- N,N′ disalicylidene-1,2 propanediamine.
- N,N′ disalicylidene ethylene diamine.

The use of metal deactivators in distillate fuels to meet requirements of military and commercial specifications is not mandatory. However, the refiner uses them extensively as an assist to the antioxidant or stabilizer employed in order to reduce the amount of the latter materials used.

Metal deactivators are evaluated by storage stability tests mostly in conjunction with antioxidants or stabilizers.

Antioxidants. These organic compounds when added to distillate fuels, particularly of the aviation gas turbine type, in concentrations of 0.5 to 35 pounds per thousand barrels serve to arrest gum and sludge formation resulting from oxidation and polymerization of the unsaturated fuel molecules present in most fuels and especially in those containing cracked stocks. Straight run fuels usually require antioxidants in

TABLE 1—Commercial Additives Currently Used in Distillates

Distillate Classification	ADDITIVE		
	Type	Purpose	Chemical Nature
Aviation Gas Turbine Fuels	Corrosion Inhibitor	Anti-rust	Polar organic compounds
	Metal Deactivator	Arrest Accelerated Gum Formation due to Trace Metals	Chelating compounds
	Antioxidant	Arrest Gum Formation	Phenols and phenol/amines
Heating Oils	Stabilizer and Dispersants	Improved storage stability	Organic and metal-organic detergents
	Metal Deactivator	Arrest Accelerated Gum Formation due to Trace Metals	Chelating compounds
	Corrosion Inhibitor	Anti-rust	Polar organic compounds
	Pour Depressant	Lower pour point	Polymeric materials
	Combustion Improvers	To prevent smoke and soot	Soluble metal compounds
Diesel Fuel	Stabilizers and Dispersants	Improved storage stability	Organic and metal-organic compounds
	Metal Deactivator	Arrest Accelerated Gum Formation due to Trace Metals	Chelating compounds
	Corrosion Inhibitor	Anti-rust	Polar organic compounds
	Pour Depressant	Lower Pour Point	Polymeric compounds
	Cetane Number Improver	Improvement in Ignition quality	Alkyl nitrates, peroxides, metal-organic compounds
	Dye	Product Identification	Azo, anthraquinone and aniline compounds

only token amounts, if any, where such products are stored and used at moderate temperature levels. Where fuels are subjected to elevated temperatures the use of oxidation inhibitors is a must, regardless of composition. Generally antioxidants are more effective in lighter fuels and are seldom used in the less volatile types of distillate fuels.

By arresting the formation of gum and sludge in storage, antioxidants prevent these deleterious materials from finding their way into fuel systems, metering and control mechanisms, resulting in trouble due to deposit lay down and filter plugging. Antioxidants must be added to fresh fuel to be effective. Additives of this type are not effective in alleviating the detrimental effects of gums and sludges preformed in the fuel prior to treatment with the additive.

The use of antioxidants is optional in aviation gas turbine fuels of the MIL type and in Types A, B and C fuels for commercial aircraft turbine use. Some refiners use them and some do not. Their use as previously mentioned depends largely on the composition of the fuel being supplied. Antioxidants approved for use in MIL type gas turbine fuels include:

- 2,6-ditertiary butyl-4-methyl phenol
- N,N′-disecondary butyl para phenylenediamine
- 2,4-dimethyl-6-tertiary-butyl phenol
- 2,6-ditertiary-butylphenol

Various methods are available for evaluation of antioxidants. These methods are usually based on measuring the gums and insoluble products developed during the aging of the fuel. The development of color bodies in the fuel can also be used as a measure of effectiveness of the antioxidant.

Stabilizers and Dispersants. To meet the demand for high octane gasoline during the war, petroleum refiners installed catalytic cracking units. In addition to producing high octane gasoline these units produced a product in the distillate fuel boiling range known as cycle stock. Following the war there was a rapid increase in demand for middle distillates for home heating and for railway diesel fuels. To meet this demand, the industry began using catalytic cycle stocks in distillate fuels.

Prior to this rapid increase in demand, practically all of the distillate fuels had been straight run products with good storage stability. To use catalytic cracked stocks it is sometimes desirable to stabilize the product by processing methods or to use additives. Additives were found that would successfully stabilize the product and at the same time have a definite cost advantage over processing methods.

Today stabilizing additives are quite universally used throughout the industry. Some estimates are that 90 percent of all No. 2 fuel sold on the domestic market contains a stabilizing additive of some kind.

The number of stabilizing additives on the market is quite large. This is partly due to the fact that additives must be selected for a specific fuel and it is not uncommon to find an additive that will be effective in one fuel but not in another. Stabilizing additives vary widely in their chemical composition. They include such compounds as alkaline earth sulfonates or phenates, polymeric materials and organic amines. These additives are commonly used in concentrations of 5-60 pounds per thousand barrels in combination with metal deactivators.

There is a large number of additive evaluation tests described in the literature. These are usually based on a measurement of the insolubles or color bodies developed under accelerated storage conditions. The ASTM is engaged in developing a standard stability test method and it is sincerely hoped they will be successful in the near future.

Pour Depressors. Pour depressors for distillate fuels have not been used extensively in the past mainly because of economic reasons. There are a number of well-known pour depressors on the market. In general, however, these materials have been developed for lubricating oils and have not been found to be entirely satisfactory for use in distillate fuels. These additives are mostly polymeric materials that have the property of changing the crystalline properties of the wax. In fuel oils they are used in concentrations ranging from 0.01 to 0.1 percent. Pour depressors for distillate fuels will probably develop into a sizeable future market if a satisfactory economical product is developed.

Pour depressors are evaluated by the well known ASTM test for Cloud and Pour Point.

Dyes. Oil soluble dyes are not used extensively in present day distillates. Occasionally they are added to brand name products such as diesel fuel in order to identify the grade and quality of product, in the mind of the customer, with the manufacturer. The dyes employed for this purpose are usually organic compounds of the azo, anthraquinone or aniline types. Azo benzene-4-azo-2-naphtol is an example of a red dye used. Dosages of dye for distillate fuels may range from 0.5 to 0.7 pounds/1,000 barrels of fuel.

Cetane Number Improvers. These compounds are employed to upgrade the ignition quality of distillate fuels used in medium and high speed diesel engines. At times it may not be possible or feasible to meet specification requirements for ignition quality by conventional refinery processing techniques or by blending practices, retaining at the same time other desirable fuel characteristics. Cetane number improvers can be useful in such instances. A typical example of such a case is the requirement that all diesel engines used by the Ordnance Dept. by 1960 must operate on JP-4 fuel of 40 minimum cetane number. In order to meet this requirement the use of a cetane number improver such as amyl nitrate may be necessary.

The more effective cetane number improvers are the alkyl nitrates, such as amyle and butyl nitrate; carbamates, such as isopropyl-n-methyl-n-nitro carbamate; and peroxides, such as ditertiary butyl peroxide and certain metallic pounds such as sodium. These materials are used in concentrations ranging from 0.1 volume percent, depending upon the composition of the fuel and the cetane number improvement desired. Ordinarily, cetane number improvers are considerably less effective in cracked

stocks than in straight run. Where 0.25 volume percent of amyl nitrate may give a jump of 7.0 cetane numbers in a straight run fuel, it will effect an increase of only about 3.0 cetane numbers in a catalytically cracked stock. The only additives which have been used commercially to any great extent are the alkyl nitrates. Many effective additives are unsuitable with respect to fuel corrosion, gum formation, stability and/or price.

Cetane number improvers have the disadvantage of being too expensive at the present time to be used in most fuels. The fact that they are less effective in catalytically cracked stocks than in straight run stocks is a further disadvantage since it is in the former materials that they are most needed.

The ASTM cetane engine is used to evaluate cetane number improvers by determining the cetane ratings on fuels with and without additive.

Combustion Improvers. Chemicals that catalyze combustion, resulting in reduced smoke and soot formation, are referred to as combustion improvers. Although additives for improving combustion were among the first additives proposed for fuel oil, they have never received wide acceptance. They are usually soluble metal-organic compounds containing such metals as copper, iron, chromium, cobalt, nickel or manganese. These metals are known pro-oxidants and in distillate fuels will reduce the storage stability resulting in the formation and deposition of insolubles in the fuel storage tank. They also have the undesirable feature of producing metallic oxide ash on combustion which is objectionable in both diesel engines and in heating plants.

Under normal conditions there is little need for combustion improvers in distillate fuels since good combustion is obtained without difficulty with a high quality fuel and a properly adjusted burner. The use of combustion improvers has found limited use in residual fuels.

Combustion catalysts can be evaluated in actual burner tests or by measuring the ignition temperature of soot deposits.[4, 5, 6]

WHAT ABOUT NEW ADDITIVES?

Increasing demand for distillate fuels will undoubtedly assure an expanding market for those additives now used. What about new areas of additive research activity? In the authors' opinion there are several. The development of dual purpose additives such as stabilizers and pour depressants is one. In addition, there appear to be promising new areas into which additive research might be expanded. A listing of these is given in Table 2.

The suggestions given in this table pertain to equipment performance problems confronting the consumer which possibly can be fully or partly solved by the additive route. Some of these problems are limited to specific uses, others are recent developments, and a few represent problems for future consideration. The market potential in some of the suggested areas may not be large enough to justify the necessary development expenses. The economic considerations in these cases would have to be established.

TABLE 2—Suggested Areas of Additive Research

Distillate Fuels	ADDITIVE	
	Type	Purpose
Aviation Gas Turbine Fuels	High Temperature Thermal Stability	Arrest deposit formation at temperatures between 500°F.—1000°F.
	Moisture Control	Prevent Icing
	Freeze Point Depressant	Self Explanatory
	Combustion Improver	Blowout Prevention
	Anti-static	Fuel Handling Speed-Up
Heating Oils	Combustion Improver	Prevention of Soot, Carbon and Smoke
	Pour Point Depressant	To meet lower pour requirements
Diesel Fuels	Cloud Point Depressant	Prevention of Filter Plugging
	Effective cetane number Improver for cracked stocks	Improvement in ignition quality
	Cold Starting Additive	Improve starting without aids at temperatures between 0°F. 30°F.
	Moisture Control	Prevention of filter and fuel line plugging due to ice
	Exhaust Odor Improvement	Self Explanatory
	Oiliness Agent	Prevention of injection equipment wear with low viscosity fuels

High Temperature Thermal Stability. Fuels for turbine aircraft operated at supersonic speeds are expected to reach temperature levels in excess of 500° F. This condition, in part, is due to the fact that the high skin temperatures encountered will tend to elevate the temperature of the fuel, and more importantly, the fuel may be required to serve as a heat sink for cooling the lubricating oil and other components.[9]

The production of fuels suitable for these temperature levels and in the quantities apt to be required may be difficult of achievement without some assist from additives to prevent fuel deterioration by coking and the formation of gums and sludges. These materials are undesirable since they lead to fuel filter and heat exchanger plugging and restrictions in fuel flow, as well as in seizure of fuel control mechanisms.

It appears that here is an area where a great deal of research effort can possibly be justified. The subject is not new; however, a very considerable amount of work is already being done in this area of additives research by both the chemical and petroleum industries.

Moisture Control. The freeze-out of moisture in aviation gas turbine fuels poses a problem of considerable magnitude. At high altitudes the ice formed causes stoppage of fuel flow by plugging fuel filters by passes and transfer valves. Attempts are made to remove this moisture before it ever reaches the aircraft by means of coalescing type fuel filters and by heaters in the fuel system of the aircraft itself. However, it would seem that an assist in this problem might be provided by additives.

The moisture control problem also crops up in diesel equipment that is operated at below freezing temperatures. Materials of the alcohol type have been used with some success for

this purpose. However, there seems to be room for some improvement in this area, possibly in the form of a miscible, dual purpose additive with good ignition quality characteristics which would provide not only moisture freeze-out protection, but reduce injection pump and nozzle plunger wear as well.

Freeze Point Depressants. It is often difficult for the refiner to meet freeze point requirements of aviation gas turbine fuels of the kerosine type without resorting to special processing and treating or to end point cutting. These methods may be undesirable because of loss of yield of product. An effective ashless type additive which would have the property of lowering the freeze point of such fuels from, say —40° F. to below —50 F. would be desirable, if such an additive could compete economically with more conventional methods of obtaining good freeze points. The authors' realize, of course, that solving this problem with additives may be almost out of the realm of possibility from a technical point of view.

Combustion Improvers. Additives which can be added to jet fuels to promote cleaner combustion, give less smoke, and prevent combustion blowout at high altitudes have, in the past, been given some attention. These efforts should be continued.

Anti-Static Additives. Several major chemical and petroleum companies have undertaken the development of additives for reducing the static hazard in the handling of aviation gas turbine fuels and allied distillates. Considerable success has been achieved in this direction but considerably more work in this area seems to be indicated to achieve completely satisfactory results.

Cloud Point Depressants. One of the major problems in the use of diesel fuels at low temperatures is the plugging of equipment fuel filters with wax. For mobile equipment exposed to the elements, such as construction equipment, the limiting factor is usually the cloud point of the fuel. Pour points of diesel and heating oils can be lowered substantially by depressants, but to the authors' knowledge no successful research effort has been expended in the development of additives which will lower the cloud point. The usual method of overcoming this problem is to switch to the use of lighter fuels during cold weather. However, as greater demand is made on the lighter stocks for other purposes, for example, turbine fuels, the problem may become more acute in the future.

Cetane Number Improvers for Cracked Fuels. As previously stated, most existing cetane number improvers are appreciably more effective in straight run fuels than in catalytical cracked fuels or blends of straight run and cracked fuels.

There is a need for an economical cetane number improver that is more effective in cracked fuels than cetane number improvers presently available.

Cold Starting Additive. Auxiliary starting aids of various types are usually employed for starting diesel engines at low temperatures. This method of engine starting has proven very effective. There is, however, an area between 10° and 30° F. where it would be desirable to start diesel engines on their regular fuel without having to resort to special aids. Depending on the fuel used and on the engine design, most diesel engines can be started on regular diesel fuels at temperatures of 20° F. or above without aids. An effective additive which would extend this minimum starting temperature would be helpful. This could pose a rather difficult problem for the additive people. However, there have been indications in the literature that it is not beyond the realm of technical possibility.

Exhaust Odor Improvement. The exhaust odor of diesel engines along with exhaust smoke has come in for criticism in areas where traffic congestion is a problem. Although there may not be a great deal that can be done about the exhaust smoke problem by means of additives, except as mentioned under combustion improvers, there has been some indication that the exhaust odor from diesel engines can possibly be improved via the additive route. Further work along this line may be warranted.

TABLE 3—Current and Projected Demand for Distillate and Residual Fuels

FUEL	Thousands of Barrels/Day		
	1957	1960 (Est.)	1965 (Est.)
Aviation Gas Turbine Fuels			
Military	183	265	300
Commercial	3	80	205
General Aviation	9	10	15
Total Jet	195	355	520
Heating Oil	1033	1170	1380
Diesel Fuel	503	708	767
Total Distillate	1734	2233	2667
Percent Increase over 1957	....	28	....
Percent Increase over 1960	....	....	25
Residual Fuel	1480	1570	1735

Oiliness Agent. Some high speed diesel engines prefer fuels which fall within the ASTM 2-D classification. There are other makes of engines which perform better across their speed and load range on ASTM 1-D type fuels. Engines designed to burn 1-D fuels can and frequently do operate on 2-D fuels successfully, usually under full load conditions. However, 1-D fuels may be too low in viscosity to operate with complete satisfaction in those engines designed to burn the heavier fuels. Two difficulties may be caused by using fuels of too low viscosity: (a) loss of power and economy due to excessive fuel leakage past injection pump plungers, (b) increased injection equipment wear, particularly where fine particles of dirt or rust are present in the fuel.

A polar type addition agent for 1-D fuels possibly could compensate for their lower viscosity so that under certain circumstances, where engines of both types are used, 1-D and 2-D fuels could be used interchangeably. This would obviate the need for handling two grades of fuel.

HOW MUCH WILL BE USED?

In order to provide a basis from which additive requirements can be gaged there is shown in Table 3 the distillate and residual fuel demand projected from 1957 to 1965. The projected estimates represent current thinking.[1, 2, 3, 7, 8]

Table 4 gives information on the present and future consumption of

additives now in commercial use for the years 1958 through 1961 based on fuel volumes given in Table 3. The data contained in this table are broken down to show the estimated fuel volume for the years mentioned, the additive volume and the dollar value of these additives. The basis for these data are the known fuel consumption figures for 1958 and the estimated future demand for distillate fuels for 1959, 1960 and 1961. Information furnished by several major oil companies on additive volume as related to total distillate fuel marketed served as a basis for the projection of these additive figures on an industry-wide basis. The assumption was made that the additive volume as it is applied to these companies would be more or less typical of the industry. Average dosage and per pound cost figures for the various additives were generally available from the additive suppliers. In view of the assumption that had to be made the data presented in this table are intended to indicate trends only.

There has been no effort made to estimate the future demand for additives not now used in some volume by the petroleum industry. This applies not only to antioxidants and metal deactivators for jet fuels, cetane number improvers for fuels used for diesel engines but to those additives which might be developed in the future as discussed under the suggested areas for research. Increasing use of such additives could swell the total market volume for additives by a subtantial amount. Neither has consideration been given to that segment of the additive market involving direct sales to consumers.

As will be noted from the table it is estimated that the volume of existing types of additives used by the petroleum industry will increase from nearly 14 million pounds in 1958 to 15.8 million pounds in 1961. Larson[7] in 1955 indicated the volume of additives used by the petroleum industry at that time to be about 13 million pounds, including cetane number improvers. With the trend towards the use of lower cetane number fuels for diesels of the locomotive type the demand for cetane number improvers has decreased considerably. The recent military requirement that all dieselized ground equipment must be able to burn JP-4 fuel could spur the future demand for cetane number improvers.

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TABLE 4—Estimated Additive Consumption

Fuel	Type	ADDITIVE # /M	ADDITIVE Use	1958 Fuel Vol.[a]	1958 Add. Vol.[b]	1958 Add. Value[c]	1959 Fuel Vol.[a]	1959 Add. Vol.[b]	1959 Add. Value[c]	1960 Fuel Vol.[a]	1960 Add. Vol.[b]	1960 Add. Value[c]	1961 Fuel Vol.[a]	1961 Add. Vol.[b]	1961 Add. Value[c]	Remarks
Jet Fuel																
MIL Grade				79.5			89.3			96.7			102.0			
	Antioxidant	8.4 (Max.)	Optional	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	No data available.
	Metal Deactivator	2.0 (Max.)	Optional	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	No data available.
	Corrosion Inhibitor	7.5	Mandatory	....	0.60	0.400	....	0.67	0.469	....	0.73	0.511	....	0.77	0.539	
	Anti-Static	0.5-20.0	Not Approved	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	No data —not widely used.
Commercial				5.5	.....	.....	24.1	.....	.....	32.9	.....	.....	41.5	.....	.....	
	Antioxidant		Optional	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	Metal Deactivator		Optional	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	Corrosion Inhibitor	7.5	Optional	....	0.041	0.029	....	0.18	0.126	....	0.25	0.175	....	0.31	0.217	Widely used but not required.
	Anti-Static	0.5-20.0	Not Approved	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	No Data—Volume small.
Heating Oil				394.0	.....	.....	410.0	.....	.....	427.0	.....	.....	442.0	.....	.....	
	Stabilizer	15.0		....	4.250	2.550	....	4.430	2.660	....	4.610	2.770	....	4.770	2.862	
	Metal Activator	0.5		....	0.138	0.244	....	0.144	0.255	....	0.150	0.265	....	0.155	0.270	
	Corrosion Inhibitor	10.0		....	3.740	2.244	....	3.900	2.340	....	4.060	2.436	....	4.200	2.520	
	Pour Depressant	90.0		....	0.071	0.021	....	0.075	0.023	....	0.077	0.023	....	0.080	0.024	
Diesel Fuel				247.0	.....	.....	253.0	.....	.....	258.0	.....	.....	264.0	.....	.....	
	Stabilizer	15.0		....	2.670	1.601	....	2.730	1.640	....	2.790	1.674	....	2.850	1.710	
	Metal Deactivator	0.5		....	0.088	0.151	....	0.088	0.156	....	0.090	0.160	....	0.092	0.163	
	Corrosion Inhibitor	10.0		....	2.350	1.410	....	2.400	1.440	....	2.450	1.470	....	2.510	1.506	
	Pour Depressant	90.0		....	0.040	0.012	....	0.046	0.014	....	0.047	0.014	....	0.048	0.014	
	Cetane No. Improver	0.1-0.3 .. (Vol.)		....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Vol. minor but could become sizable.
	Dye			....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	No data available—minor.
			Totals	....	13.99	8.662	....	14.66	9.123	....	15.25	9.498	....	15.79	9.825	

Notes: [a] Fuel volume in millions of barrels per year.
[b] Additive volume in millions of pounds.
[c] Additive value in millions of dollars.
Corrosion inhibitor for heating oils and diesel fuels based on 95% inhibition of all fuels used. Price: $0.60/#
Corrosion inhibitor for jet fuels based on 100% inhibition. Price: $0.70/#.
Stabiliser used based on 72% inhibition of all fuels. Price: $0.60/#.
Metal deactivator used based on 70% inhibition of all fuels. Price: $1.77/#.
Pour depressor used based on 0.2% inhibition of all fuels. Price: $0.301/#.

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. . . In Motor Oils

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THE AUTOMOTIVE industry has made spectacular progress in the design of automotive equipment during the last 25 years. Not as obvious, but equally spectacular, have been the improvements made to the oils for lubricating this equipment. Each advance in engine design called for improvements in the lubricating oil, and indeed many of the design advancements could not have been made without improved oils. Some of the changes that have occurred in operating conditions and engine design will be discussed briefly since these changes are illustrative and have had a profound effect on the types of additives that have been developed.

Diesel Engine Oils. It might be well to consider briefly the operation of a diesel engine so that the problems of the engine lubricant can be better understood. The high speed diesel engine, such as is used in long-haul truck fleets, operates at high load and high temperatures for long periods of time. Most of the deposits formed in these engines come from oxidation of the lubricating oil and from fuel combustion products.

Diesel fuels contain relatively high percentages of sulfur, and in the combustion process some of the sulfur is changed to sulfur trioxide. Most of the sulfur trioxide goes out the engine exhaust, but some of it reacts with the lubricating oil to form sludge. This sludge, in combination with oil oxidation products, is the deposit-forming material that the dispersant or detergent additive must suspend. This acid must also be neutralized or made inert, otherwise it will cause engine wear by attacking ferrous metal parts. Oil oxidation and bearing corrosion must also be controlled.

One type of oil developed in 1948 contained additives accounting for 15-20 percent of the bulk oil. More recently, oils have been developed for marine diesel engines which are being powered with residual fuels of high sulfur content. These oils contain 30-40 percent of alkaline additives and reduce cylinder wear by neutralizing acid formed by fuel combustion. At today's additive prices, the original military oils developed during the early 1940's, would contain 4 or 5 cents of additive per gallon of oil; whereas, the new marine cylinder lubricants contain ten times this amount.

Gasoline Engine Oils. By contrast with the diesel engine, the gasoline engines developed during the postwar period have presented different problems in lubrication. There has been a sharp increase in the horsepower of passenger cars without much change in over-all car weight. As a result, a smaller and smaller percentage of available horsepower is used in normal town driving. The engine loafs most of the time and under these conditions operates at low oil temperatures. Nevertheless, increased compression pressures have increased the high load combustion temperatures from 2,700° F to over 4,500° F during the postwar period. Thus, an oil must be able to withstand these higher temperatures yet be effective in low temperature service.

It was soon recognized that stop-and-go driving was much more severe in its demands on the lubricating oil than high-speed driving. In gasoline combustion, partially burned fuel contains many highly reactive chemical compounds such as aldehydes, ketones, and low molecular weight acids. These chemicals, together with water formed by combustion, are forced past the piston rings and find their way into the engine crankcase. The water condenses. Under conditions existing in the engine crankcase, the partially burned fuel polymerizes. Thus the water, partially burned fuel, lead compounds, and acid from the fuel combustion are the major sources of engine deposits and wear in gasoline engines.

Although the wartime heavy-duty oils were effective in reducing wear, they were only moderately effective in controlling sludge deposits in this type of service. Increased compression ratios have made combustion chamber deposits more critical, and it has not been possible to utilize extremely high levels of metal-containing additives effectively in motor oils.

Several improvements have been made in gasoline engine oils following the war. Premium oils which contained relatively small amounts of detergent and moderate amounts of inhibitor were introduced in 1948. In 1950, heavy-duty oils similar to the diesel engine lubricants became common. In the following years, service station oils were increased in compounding level up to, and sometimes above, that required by the U.S. Army Ordnance Department's 2-104B, Supplement 1, requirements. This trend has continued up to the present with more and more first-line service station oils being of this level of performance.

Further increases in horsepower and changes in engine design brought additional problems for the petroleum industry. The widespread use of hydraulic valve lifters, changes in the cam lobe profiles, and the use of heavy valves springs caused extremely high pressures to be developed between the lifter and lobe surfaces. Pressures that are calculated to be in the order of a quarter of a million pounds per square inch are reached approxi-

mately ten thousand times for each mile that a car, powered by a modern V-8 engine, is driven. It was necessary to develop oils with very high load-carrying properties in order that these and similar engine parts could be adequately lubricated.

Multigrade Motor Oils. Multigrade motor oils are considered one of the most important developments in gasoline engine lubrication during the postwar period. These oils are not new, having been first marketed in the 1930s. New advances in additive and oil technology, and new engines that could better utilize the advantages of these oils brought them to commercial importance in 1953.

Multigrade oils differ from conventional oils in that they consist of mixtures of light lubricating oil (10W base oil) and high molecular weight polymers rather than light and heavy lubricating oils. Because of their high viscosity index, that is, their low rate of viscosity change with temperature, these oils meet the requirements of two or more viscosity grades.

The viscosity index improvers are giant molecules ranging in molecular weight from 100,000 to a million or more. This is in contrast to petroleum hydrocarbons in the lubricating oil range which have molecular weights of about 500. C. W. Georgi[5] has a homely analogy which describes these oils well: "A polymer-mineral oil blend may thus be likened to a handful of spaghetti mixed into a cup of peas; the spaghetti representing the polymer molecules and the peas the oil molecules."

When the polymers are added to lubricating oils, they have a relatively greater effect on high-temperature viscosities than on low-temperature viscosities. This is because the giant molecules are random coils that swell at high temperatures and contract at low temperatures. This is illustrated in Figure 1.

Most of the benefits in multigrade oils come from the proper choice of additives and from the dependence of the oil viscosities on shear, rather than from their high viscosity index. When properly formulated, these oils provide improved fuel mileage, easier starting, better control of low temperature deposits, improved wear control, and adequate load-carrying properties.

In more recent times, oils containing detergents which are not metal salts have been developed. These oils are less prone to contribute to combustion chamber deposits and this is becoming of increased importance in the new high compression engines.

Two opposing trends have developed during the postwar period. On the one hand, the military services require all-purpose lubricants that will lubricate all types of equipment, both diesel and gasoline, under all types of service conditions. In contrast to this, there has been a growing trend to develop oils that are designed for specific types of service and equipment. This insures that performance features will not be compromised as is sometimes the case when one oil is required to serve several purposes. This trend is evident in that special oils have been developed for use by railroads, in outboard engines, in light aircraft, and similar equipment where specific problems of design and operation make the typical compounded oils unsatisfactory from the standpoint of maximum performance and engine life.

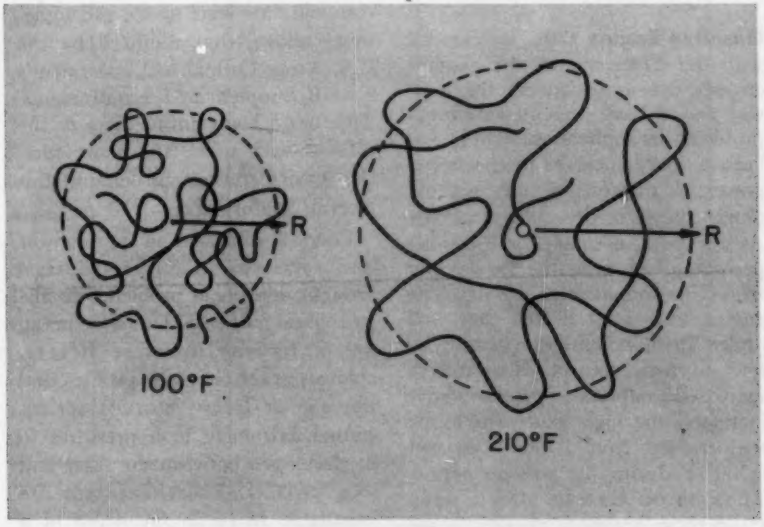


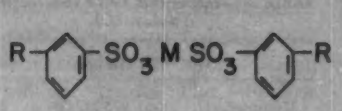
FIGURE 1—Here is a graphic representation of a polymer molecule in oil at two temperatures. Thickening power is proportional to the cube of the hydrodynamic radius, R. Higher temperatures cause R to increase polymer solubility.

Additive Types and Functions. The types of chemical compounds that have found widespread use in gasoline and diesel oils are illustrated in Figure 2. In some cases, the chemical formulas shown are idealized or are only approximate. Many additives, such as those derived from petroleum or those involving phosphorus-sulfur reactions may be mixtures of several chemical types. In some cases their exact structure is unknown. In addition, some additives are chemical combination of two or more of the types illustrated. Many additives are multifunctional. That is, they affect several properties of the lubricating oil. In such cases, they have been classified by their principle use.

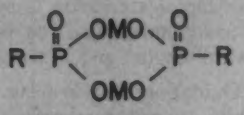
Additives are usually manufactured and sold as oil solutions ranging 10 percent to 100 percent active ingredient. Selling prices range from 10 cents to several dollars per pound, depending on chemical type and active ingredient concentration. As an average, a typical additive would contain about 50 percent active ingredient and sell for about 25 cents per pound or $2 per gallon. Additive manufacturers combine as many as six or eight different compounds and sell packaged additives in order to provide all of the desired properties in a lubricating oil.

Detergent or dispersant com-

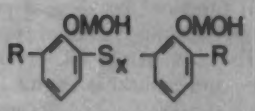
Detergent-Dispersant Additives



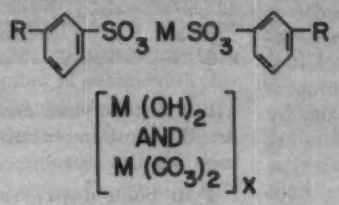
Metal Sulfonates



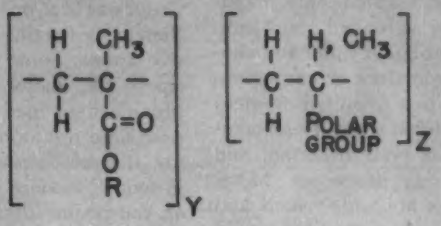
Metal Phosphates



Metal Phenol Sulfides

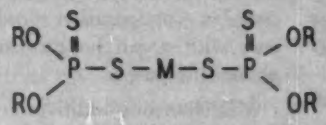


Overbased Metal Sulfonates

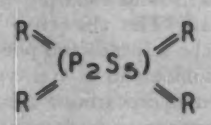


Polymeric Detergents

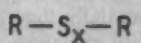
Oxidation and Bearing Corrosion Inihibitors



Metal Dithiophosphates

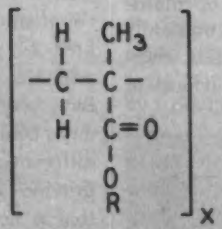


Phosphorus Pontasulfide-terpene Reaction Products

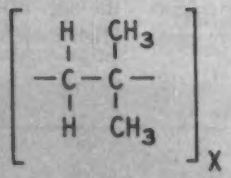


Sulfurized Hydrocarbons

Viscosity Index Improvers

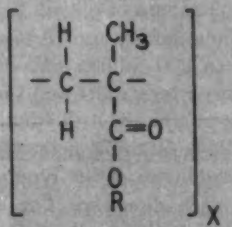


Polyalkylmethacrylates

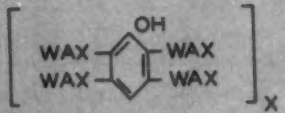


Polyisobutylene

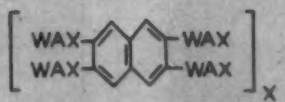
Pour Point Depressants



Polyalkylmethacrylates



Phenol Condensation Products



Naphthalene Condensation Products

FIGURE 2—In some cases the exact structure of the additives is unknown. In the idealized or approximate formulas shown here, M represents barium, calcium, or mangnesium while R represents various molecular weight hydrocarbons.

pounds function[5] by keeping potential sludge-forming material peptized or dispersed in the oil. Some are alkaline and neutralize engine acids. The metal salts of sulfonates are the most widely used detergents in crankcase oils. Most sulfonates are manufactured from selected petroleum fractions. Over-based sulfonates contain metal hydroxides or carbonates in excess of that required to neutralize the sulfonic acids. These compounds provide both dispersant and acid neutralizing properties. Metal phenol sulfides are widely used and function as acid neutralizers, mild antioxidants, and dispersants. Metal phosphonates likewise are multifunctional and have these same properties. They are becoming of increased commercial importance.

A new class of dispersant additive for multigrade oils was mentioned earlier. These are called polymeric detergents. Essentially they are high molecular weight polymers, such as are used as viscosity index improvers, which combine organic polar groups in the polymer chains. Groups such as polyglycols, pyrrolidones, amides, and carboxylic acids have been used. Polymeric detergents are truly multifunctional. They are more effective than the metal-containing detergents in controlling low temperature gasoline engine deposits, they improve viscosity index, reduce pour, and control engine and bearing wear.

Oxidation and bearing corrosion inhibitors reduce the tendency of oils to oxidize and provide a protective coating on bearing surfaces, thereby protecting them from corrosive attack. Some compounds, principally the metal dithiophosphates, provide high load carrying properties. Zinc dithiophosphates[9] are, by far, the most widely used inhibitors in today's modern oils. It is this type of compound that provides high load carrying properties to oils in addition to being very effective in controlling oxidation and bearing corrosion. The use of metal dithiophosphates, principally the zinc salt, has increased sharply in the past few years. The reaction product of cyclic terpenes and phosphorus pentasulfide and several types of sulfurized hydrocarbons are also used in engine oils.

Viscosity index improvers were developed to improve the viscosity-temperature relationship of oil beyond that which could be economically obtained by refining methods. The recent introduction of multigrade oils has increased markedly the use of additives of this class. High molecular weight polymers of alkyl methacrylate and isobutylene are the most important compounds used for this purpose.

TABLE 1—Estimated 1959 Lubricating Oil Sales, U.S.

	Gallons	Percent
Automotive:		
Motor Oil	975,522,000	48.4
Chassis and Transmission	92,958,000	4.6
Total Automotive Lubricants	1,068,480,000	53.0
All other Lubricants	947,520,000	47.0
Total	2,016,000,000	100.0

Pour point depressants permits the economic production of low pour point oils without requiring severe dewaxing. Polyalkyl methacrylates, similar to the aforementioned viscosity index improvers, and complex condensation products of wax with naphthalene and with phenol, are used.

Miscellaneous additives are added to lubricants to reduce foaming, inhibit rust, and impart additional load carrying properties. Dyes are used to modify the appearance of lubricants. There have been literally tens of thousands of chemical[6,7,8,11] compounds that have been evaluated as potential lubricating oil additives, and thousands of patents have been granted in this field. Today's compounded oils contain many different additives, each selected to provide some performance feature that is needed in the finished oil.

Market for Lubricating Oils and Additives. The estimated domestic sales of automotive lubricants in 1959 is shown in Table 1. Over a billion gallons of oil will be required for automotive use. An additional 100 to 200 million gallons will be required for export and for government purchase. Of the total amount, probably 60 or 70 percent will contain additives of the type that have just been discussed. The estimated market[1,2,3,4,10] for the additives used in compounding these oils is shown in Figure 3. The requirement for conventional detergents is about 325 million pounds. Viscosity index improvers and polymeric detergents

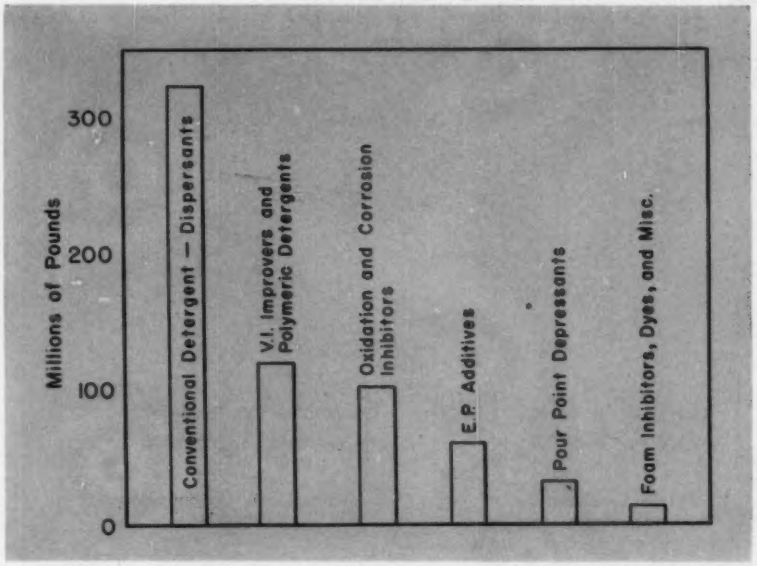


FIGURE 3—Of the total amount of oil required for automotive use, probably 60 or 70 percent will contain additives. Here is the estimated market for oil additives for 1959.

add another 120 million pounds. One-hundred million pounds of oxidation and corrosion inhibitors will be needed, with extreme pressure, pour point depressant and other additives making up the total of about 643 million pounds. The value of these chemicals is estimated to be $150 million to $175 million.

The bulk of the additives are manufactured by seven or eight chemical or petroleum companies. An equal number of petroleum companies manufacture one or more additives for their own use. There are many additional chemical and oil companies who manufacture miscellaneous additives or additive intermediates, and there are literally hundreds of suppliers of raw materials and services.

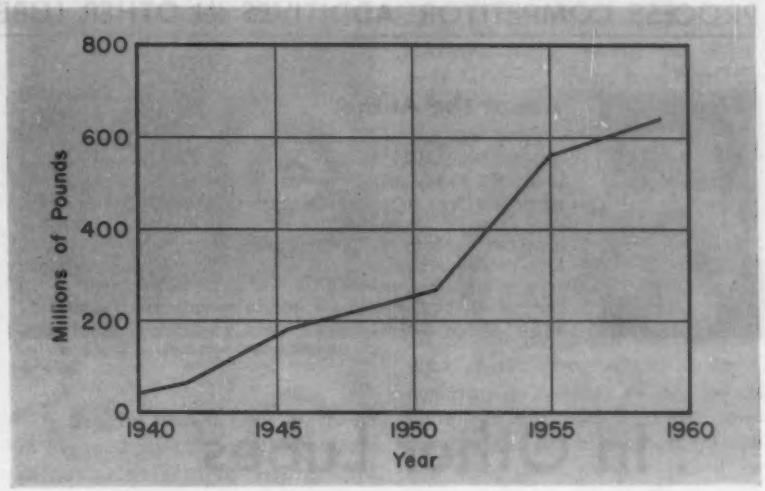


FIGURE 4—On an over-all basis the additives market has increased steadily in volume.

A decrease in the market for lubricating oils is now a general trend, and this of course has an effect on the additives that are used. Between 1938 and 1958, crankcase capacity has been reduced from an average of 6.6 quarts to 4.8 quarts. The motoring public have extended oil-drain periods beyond the change periods recommended by the American Petroleum Institute. Engine design changes have reduced oil consumption and improved oils have maintained engines at low oil consumption rates for long periods of use. As a result, the use of engine oil per 100 gallons of fuel is only 50 percent as great as it was 10 years ago.

Reduced export of additives and compounded oils is another factor reducing the requirements for these products.

Nevertheless, there are compensating factors which result in a continued increase in the amount of additives required. The newer engines cannot operate satisfactorily on straight mineral oils even though these uncompounded oils are of the highest quality. Therefore, the use of oils containing additives is increasing as older cars become obsolete and are replaced by newer ones.

On an over-all basis the additives manufactured and sold have steadily increased in volume. This is illustrated by Figure 4 which shows the estimated production volume between 1940 and the present.

Future Trends. During the last 25 or 30 years design changes in engines have caused them to be much more complicated. In addition, operating conditions have become much more severe. These changes have required a continued improvement in engine lubricants.

This trend will surely continue. Diesel engines will be called upon for more power. This will be obtained by supercharging and turbocharging these engines. The use of lower grade economy fuels will put a greater load on the engine lubricants. This will require more additives and more effective ones. Non-metal-containing additives will be required as the higher output engines become less tolerant of the metal ash contributed by existing additives.

In gasoline engines the emphasis will be on lubricants for high speed, better breathing, and more powerful engines. With higher compression ratios, combustion chamber deposits will become more critical. This will require nonash or low ash-containing oils. Increased stop-and-go city driving will call for additives which are more effective under these conditions of operation.

Petroleum technologists now have a better understanding of the physical and chemical changes that take place in an engine lubricant during use. More precise laboratory engine tests have been developed and better correlations between laboratory and field performance are being obtained. New research tools, such as the electron microscope and radioactive engine parts, will help the people in lubricating oil and additive research meet these challenges of the future.

(Originally presented before a meeting of the Commercial Chemical Development Association, Mount Pocono, Pa., May 1959).

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About the Author

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. . . In Other Lubes

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SELECTED ADDITIVES and chemicals are used extensively in lubricating oils other than motor oils. Some of these other oils, which will be reviewed in this discussion, are listed in Table 1 along with the estimated volume and the dollar value of their additive ingredients. The volume and cost data shown in this table and throughout the ensuing discussion represent the author's best estimates based on available information and certain assumptions. These data are not intended to be precise but only to serve as guides to place the various items in their proper perspective. It will be noted from Table 1 that collectively the various oils to be discussed represent a substantial market for additives.

TABLE 1—Estimated Annual Additive Consumption

	Millions of Pounds	Millions of Dollars
Automatic Transmission Fluids	32	7.4
Auto. & Ind. Gear Oils	40	11.0
Ind. Turbine—Circulating Oils	5	4.4
Other Ind. Lub. Oils	5	2.0
Aircraft Hydraulic and Gas Turbine Oils	5	4.0
	87	28.8

Figure 1 gives a more meaningful picture of the amounts and types of chemicals contained in the 87 million pounds of additive required for oils other than motor oils. The difference in the total pounds of additive and total pounds of base ingredients is diluent petroleum oil used in many additives for easier processing and handling.

In addition to the additives used in the oils shown in Table 1, for certain industrial and aircraft applications there is a requirement for lubricants that are entirely synthetic in nature. Since these synthetic oils might somewhat facetiously be considered as petroleum oils containing 100 percent additive, they will be touched on briefly later in discussion.

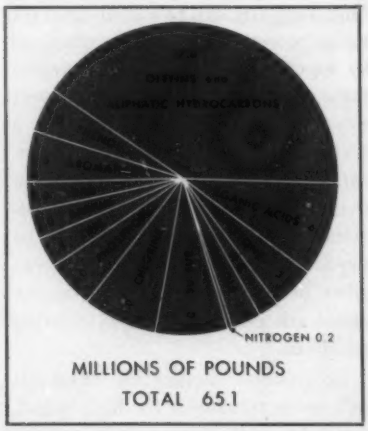

FIGURE 1—In the 87 million pounds of additive required for oils other than motor oils, many different chemical types are used.

Automatic Transmission Fluids. It is doubtful that any single lubricating oil is ever called upon to perform so many important functions and to meet so many critical requirements as the lubricant or fluid used in passenger car automatic transmissions. To allow the complex automatic transmission to perform satisfactorily, the transmission fluid must act as the following:

- A power transfer medium.
- A hydraulic medium for delicate control mechanisms.
- A lubricant for gears, clutch plates, bearings, etc.
- A heat transfer medium.

To perform these multiple functions satisfactorily, the oil must meet exacting physical property and performance requirements. Table 2 shows some of the important properties of an automatic transmission fluid and indicates whether the desired property is achieved principally by base stock or by additive selection. Although base stock is important, it will be noted that additives contribute substantially to a satisfactory formulation.

TABLE 2—Automatic Transmission Fluid

Desired Property	Obtained Principally By
Fluid at Low Temperature Low Volatility Compatible with Seals	Base Stock Selection
High Viscosity Index Resistance to Foaming Stable at High Temperature Proper Frictional Properties	Additive Selection

A high viscosity index or the property of showing a low change in viscosity with temperature can be achieved when polymeric viscosity index or VI improvers are added to the base oil. The VI improvers in common use today are alkyl polymethacrylates and polyisobutylenes. These materials must be selected with several criteria in mind. They must possess good VI improving effectiveness; must not cause excessive thickening so that base oils of adequate viscosity and low volatility may be used; and must not show excessive polymer breakdown and viscosity loss under high shearing conditions.

These VI improvers are generally used in concentrations in the range of 4-6 percent in modern automatic transmission fluids. This results in a requirement for some 15 million pounds of VI improver additive per year. At a weighted cost of some

20 cents per pound this represents a market value of $3 million for automatic transmission fluid VI improver.

Defoamant or anti-foam additives are usually used in lubricating oils in very small concentrations, in the order of 1 to 20 parts per million. The most commonly used defoamant is an organo silicon oxide polymer. Because of their high effectiveness, the yearly volume requirements for defoamants are relatively insignificant.

High temperature stability is also acquired largely via the additive route. Under 300° F temperature and oxidizing conditions an automatic transmission fluid should not break down to form harmful deposits and acids. To impart this property, stable base stocks must be used; however, by far the most important contribution to stability is made by proper selection of detergent and antioxidant additives. These additives are essentially the same as employed in motor oils.

Usual concentrations of the detergent-antioxidant combinations are in the order of 4-6 percent. This application, therefore, consumes about 15 million pounds per year of motor oil type detergents and antioxidants at an estimated additive market value of $4 million.

Proper frictional properties means the oil must possess sufficient "lubricity" to allow clutch plates to engage quietly and smoothly; however, it must not be so "slippery" that it will prevent the plates from "locking-up" selection of additives must be made to arrive at a proper frictional balance.

Sulfurized sperm oil has been used extensively as a so-called "anti-squawk" or "lubricity" additive for automatic transmission fluids. This material, however, has some limitations in certain formulations and newer type materials of undisclosed nature are now in use.

It is difficult to estimate the amount of additive used specifically to obtain proper frictional properties lacking knowledge of all types and concentrations; however, a very rough estimate of some 2 million pounds appears plausible. At a weighted cost of 20 cents per pound this would represent a value of $400,000.

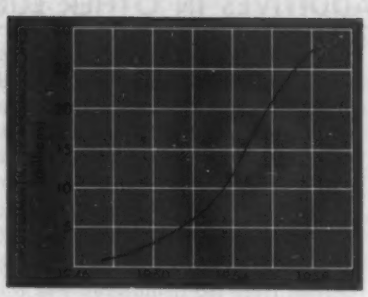

FIGURE 2—A healthy growth rate is shown for automatic transmissions in service.

A healthy growth rate is shown in Figure 2 which plots the increase in automatic transmissions from 1941-58. This growth market offers considerable inducement for research and development effort to produce improved and less costly additive materials.

Automotive and Industrial Gear Oils. The additives used in these products are referred to as a class as extreme pressure, or EP, agents. Their use is essential to the proper functioning of heavily loaded, high speed gear units. For example, automotive rear axle hypoid gears, which offer advantages of reduced noise level and lower body design, were able to be used only after suitable EP oils were developed.

EP additives function principally as a result of their chemical activity. The automotive EP types usually contain sulfur, phosphorus, and chlorine compounds. These additives react with the metal rubbing surfaces to form anti-weld, lubricating films which prevent metal to metal contact after the oil film has been ruptured or removed by extreme pressure or high sliding velocity.

The chemical activity of the compounds, although essential to their performance, must be properly controlled in order to minimize corrosion, sludge formation, and instability of the oil. Considerable progress has been made toward this objective; however, there is a need for continued improvement to meet the ever increasing temperatures and loads encountered in modern automotive equipment.

TABLE 3—Automotive Gear Oil Additives

Chemical Type	Approx. Percent Conc. Used in Oil
Lead Soap Sulfurized Mineral Oil	10—20
Lead Soap, Chlorine, Sulfur, Fatty Oil	20—30
Phosphorus, Sulfur, Fatty Oil	15—20
Sulfur, Chlorine Compounds	8—10
Sulfur, Chlorine, Phosphorus Compounds	5—10
Zinc, Sulfur, Phosphorous, Chlorine Compounds	6—15

Many varieties of chemical compounds are used in automotive gear oils. Table 3 shows some of the more common types. Obviously in such a complex field it is not practical to list the specific names and combinations of the many chemicals used; however, a review of the patent literature is suggested to give some insight into the many and diversified compounds promulgated for this purpose. A reasonable estimate for the annual requirement for automotive gear oil additives is about 30 million pounds worth about $9 million.

In the industrial field, gears are generally more conservatively designed and operate under more moderate loads and temperatures; hence, milder types of extreme pressure additives are employed. Fatty oils, organic polar compounds, and phosphate esters find extensive use as mild extreme pressure agents for industrial gear service. Lead naphthenate plus non-corrosive sulfur compounds are used in some heavy duty industrial gear oils. To a very limited extent automotive type EP oils are used in industrial service, particularly for break-in of new gears and for some hypoid gear applications.

An estimation of the amount of additive used in industrial gear oils is complicated because usually oils designed for general machine use, steam cylinder lubrication, or bearing lubrication systems are also applied to gear lubrication. Based only on oils of the lead soap type, primarily intended for heavy duty gear service, an estimate of 10 million pounds of additive per year would appear realistic. At a cost of approximately 20 cents per pound this would represent a $2 million additive market.

Industrial Turbine-Circulating Oils. These very high quality products are used in large industrial machines where the oil is circulated to perform its functions as a lubricant and bearing coolant. Long life

(up to 10 to 20 years) is expected of these products. In addition, they must have good demulsibility or water separating characteristics and good rust protection properties. These qualities are obtained by careful selection and refining of base stocks plus incorporation of suitable inhibitors to improve antioxidant and antirust performance.

The selection of inhibitors is critical since in addition to their primary function they must not unduly detract from the good demulsibility characteristics of the base stock. The most popular antioxidant for this purpose is the tri alkyl hindered phenol type, such as ditertiary butyl para cresol. This material is generally used in concentration of 0.1 to 0.8 percent in turbine-circulating oils. This usage requires in the order of 3 million pounds per year at market value of $2,400,000.

Aromatic amines, such as phenyl α naphthylamine, are also used as oxidation inhibitors. Usually their concentration does not exceed 0.5 percent in the finished oil. Newer types of alkyl aryl amines, reported to possess less photosensitivity and less sludge forming tendency than straight aromatic amines, are now appearing on the market. The overall usage of the amine type inhibitor in turbine-circulating oils appears to be lower than the hindered phenol type. Perhaps usage in the order of 1 million pounds per year would be a fair estimate. This would have a market value of $500,000.

The rust inhibitors employed in turbine-circulating oils are compounds having a high polar attraction toward metal surfaces. By physical adsorption or chemical interaction at the metal surface they form a tenacious, continuous film which prevents water from contracting the surface. Partial organic acid esters, phosphorus containing acid esters, selected metal and amino soaps are typical of materials employed for this purpose.

The problem of obtaining compounds that are effective rust inhibitors but which do not unduly detract from the demulsibility of the base oil or cause corrosion of nonferrous metals is particularly critical. Much successful research has been carried out and there are available commercial additives to perform this desired function. On an active ingredient basis, these additives are generally used at concentrations in the order of .01 to .03 percent; however, in some cases they are supplied as dilute solutions requiring higher concentrations in the finished oil. It is estimated that about 1 million pounds of rust inhibitor on an active ingredient basis are used per year in turbine-circulating oils, having an additive market value of $1,500,000.

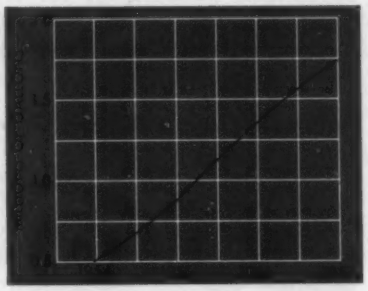

FIGURE 3—This estimate of sales for industrial synthetic fire resistant fluids does not include U. S. Navy procurement.

In the heavier grade turbine-circulating oils, particularly those employed in marine turbine-reduction gear systems, mild extreme pressure additives may be employed. These materials are usually ester types containing phosphorus, phosphorus-sulfur, zinc-phosphorus-sulfur, or chlorine groupings. In some very heavy grade oils, particularly those intended for high temperature service, selected motor oil type detergents and antioxidants are sometimes used. The volume usage of these additives for this application would be relatively minor compared to their major use in engine oils.

Other Industrial Oils. In addition to turbine-circulating oils there are several other types of industrial lubricating oils which contain additives to obtain desired functional properties. Some of these types are shown in Table 4 along with the functions performed by the additives. In many instances one additive will serve several purposes; for example, an additive which functions as an emulsifying agent to form water in oil emulsions usually contributes some antirust and antiwear protection.

Obviously, there is a great variety of additives and additive combinations used in the various industrial oils. In general the oxidation inhibitors, antirust, and mild EP or antiwear agents are similar to types previously discussed for turbine-circulating oils. The adhesive or tackiness agents are very high molecular weight polymers, such as polyisobutylene, which even in small concentrations (0.25 to 1 percent impart a sticky and stringy property to oil. This property is lost under mild shearing conditions; however, in more or less static areas such as the ends of loose fitting journal bearings it maintains its stickiness and reduces leakage from the bearing. The emulsifying agents used are usually synthetic esters or blown fatty oils. They function in oils used in all-loss lubrication systems to take water contamination into the oil forming water-in-oil emulsion. This serves as a lubricant with good antirust and antiwear properties. The synthetic emulsifying agents are usually used in concentrations of 1 to 5 percent whereas the blown fatty oils are used in the range of 10 to 20 percent.

Collectively, the additives used in the various industrial oils represent

TABLE 4—Other Industrial Oils

	Oxidation Inhibitor	Mild E.P. Agent	Rust Inhibitor	Adhesive Agent	Emulsifying Agent
Spindle Oils	X	X	X	—	—
General Purpose Machine Oils	X	X	X	—	—
Air Tool Oils	—	X	X	X	X
Compressor Oils	—	X	X	—	—
Reciprocating Steam Engine Oil	—	X	X	X	X
Machine Way Oils	—	X	X	X	—
Steam Cylinder Oils	—	X	X	—	X

a substantial volume. It would be extremely difficult to give an accurate estimate of the actual additive requirements because of the diversification of additives and oils involved. A rough estimate, however, would be in the order of 5 million pounds at a value of $2 mililon.

Fire resistant type industrial oils are becoming of increasing interest. The principal use of these products is as hydraulic fluids for hazardous applications, such as die-casting and pressure welding machines. They are also being recommended as lubricants for compressors, hydraulic mining equipment, and as steam turbine lubricants. The U.S. Navy is also procuring such products for use in hydraulic elevator and catapult systems.

There are two principal types of synthetic fire resistant fluids. One is referred to as the water base type and consists of 40-60 percent water solution of glycol containing a polymeric polyalkylene glycol thickener to obtain desired viscosity plus additives to prevent corrosion. The other is the straight chemical type, usually either a phosphate ester or a mixture of phosphate ester and chlorinated aromatics. This type fluid may contain VI improvers, rust inhibitors, and defoamants similar to those used in petroleum oils. An estimate of total sales of industrial synthetic fire resistant fluids is shown in Figure 4. These figures do not include the Navy procurement. It will be noted that sales have shown a steady increase and a healthy growth rate is anticipated.

Aircraft Hydraulic and Gas Turbine Oils. In addition to additive requirements, these products offer interesting possibilities to the chemical manufacturer in that newer types also contain synthetic rather than petroleum base oils.

The current military petroleum type aircraft hydraulic fluid contains selected, highly refined base stocks plus VI improver, antioxidant, and mild extreme pressure additives. A polymethacrylate type VI improver, of lower molecular weight and consequently more shear stable than those used in motor oils and automatic transmission fluids, is employed at 10-15 percent concentration. A hindered phenol type antioxidant at 0.2-0.5 percent concentration, tri cresyl phosphate as an antiwear agent at 0.5 percent concentration, and a red dye complete a typical approved military specification fluid. Also there is another military specification fluid which is essentially the same except it contains rust preventive additives. Combined additive requirements for these two fluids amounts to some 4 million pounds per year at an estimated cost of $3 million.

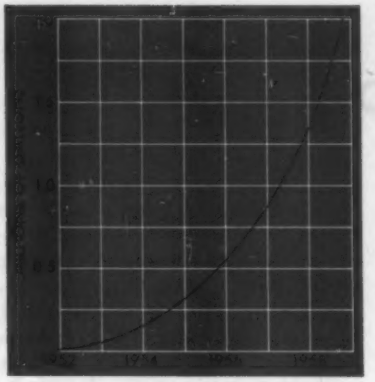

FIGURE 4—The requirement for aircraft gas turbine synthetic oils is expected to continue growing.

In the commercial field there is wide usage of the petroleum type fluid; however, in recent years there has been increasing use of a synthetic fire resistant fluid. A phosphorus containing synthetic fluid is currently being supplied by one chemical company for this purpose. The military are also seeking fluids that are thermally stable at temperatures in the order of 400° F for high speed, advanced design aircraft. Certain silicate esters and siloxane type fluids have been developed which show some promise for this application.

TABLE 5—Additives for Oils Other Than Motor Oils

Additive Type	Est. Annual Requirements
	(pounds)
Detergent	12,000,000
VI Improver	18,500,000
Anti-oxidant	9,000,000
Rust Inhibitor	2,000,000
EP and Mild EP	44,000,000
Miscellaneous	1,500,000
	87,000,000

Lubricants for gas turbine aircraft engines are also going the all synthetic chemical route. Sebacic and adipic acid esters are being used as the base fluids for current jet engine lubricants. Phenothiazine at about 0.5 percent concentration serves as an antioxidant and tricresyl phosphate at about 5 percent concentration is the mild EP additive used in some of these fluids. Lubricants for current turbo-prop aircraft are usually higher molecular weight esters or jet engine oil esters thickened with polymer. Additives similar to the jet engine lubricants are also in use. As noted by the curve in Figure 4, the volume requirement for gas turbine synthetic oils has been rising at a rapid rate and a continued rise is anticipated.

Future requirements in the gas turbine field will be for more thermally stable lubricants for high temperature, advanced design aircraft operation. Considerable development effort, sponsored to a large extent by the military, on more stable materials is in progress.

In Summary. Table 5 shows by additive type the over-all additive requirements for lubricating oils other than motor oils. Collectively these represent a substantial volume at an estimated market value of some $29 million. Also, as shown previously, these finished oils consume large quantities of base chemicals in their manufacture. Of course, coupled to these requirements is the growing synthetic oil market which also offers attractive possibilities to the chemical supplier.

Obviously, however, the science and skills of additive and synthetic oil manufacture and application are very complex and costly. Many millions of research dollars are yearly invested in ways to improve lubricating oils and additives and he who ventures into this field must openly face this challenge.

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. . . In Other Products

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ADDITIVES ARE employed to improve physical, chemical or esthetic properties. An estimated $75 million annually is spent by petroleum processors and compounders for additives in industrial lubricants, road oils, waxes and grease products. A wide variety of specific additive needs occurs within any one of these product categories.

The functions of additives can be divided into three general categories: physical, chemical and esthetic.

Physical behavior of additives can be explained and categorized as follows:

Because additive molecules must dissolve in the oil, their structure must be similar to oil molecules, but because they are added to change some property of the oil, they must be unlike the oil molecules in some respect. For most additives this is accomplished by changing ordinary oil molecules to a type called "polar" molecules.

In a fundamental study of the action of lubricating oil additives the problem becomes one of determining where these polar molecules tend to congregate and what structures they tend to form either with themselves, or with surfaces which the oil contacts. Figure 1 shows a typical polar molecule with its nonpolar hydrocarbon tail and its polar head. From our present knowledge of additives we realize that a wide range of properties and behavior patterns can occur. Furthermore, there are many possible distributions into which these molecules may exist as individually dissolved molecules. Because each of the polar molecules carries both negative and positive charges in the vicinity of its polar head, they usually tend to be attracted to one another, putting their heads together. Such aggregates are called "Micelles."

Rust inhibitors, metal deactivators, oiliness agents, and some corrosion inhibitors function as they do because the polar molecules which make up these additives tend to collect on a metal surface. The polar molecules of a detergent additive tend to exist predominantly grouped within the oil phase. Most oxidation inhibitors are not very polar and do not usually form aggregates or micelles. Anti-foam additives on the other hand, probably exist primarily in micelles at the air-oil interface.

Chemical behavior of additives can best be exemplified by the reaction of sulfur or chlorine compounds with metal surfaces during metal-working operations. These additives aid the cutting of tough steels, for example, by reacting with the surface metal to form iron sulfides or chlorides and these new compounds permit easier sliding of the cutting tool through the metal since iron sulfide or chloride salts form a surface layer having a lower shear resistance than the metal itself.

Esthetic functions required of additives are to control, improve, or change some visual or olefactory property of a petroleum product.

Industrial Lubricants. The field of industrial lubricants involves a myriad of products for a wide range of applications. We will consider a few examples representing some of the extremes of additive usage. The previous articles have touched upon the use of anti-oxidants in petroleum products so that this important area of additive applications will be neglected here. However, the use of extreme pressure agents in *metal-working lubricants* will be discussed briefly even though these additives have been described by others under gear lubricants.

Sulfur, chlorine, and to some extent, phosphorus, are the elements used in additives for metal-working lubricants in order to form low-shear salts with metals. Small amounts of sulfur can be dissolved directly in petroleum oils. Chlorine and phosphorus are always used as organic compounds and this is usually the case for sulfur also. To appeal to the workmen the odor of the additive must be tolerable with no unpleasant residual odors left on the skin or clothing. There is also a trend towards lighter colored additives to permit better visibility of the work during metal working as well as to reduce the tendency to stain the clothing.

How much does the metal-working additives business amount to? There are no good sources for this information. We know that the volume of additive business fluctuates with the ebb and rise of industrial production. We can make some rough estimates of the amount of cutting oils used and for this we refer to a study made by the Advisory Group on Industrial Practices of the ASTM. Their survey among plants served by American Society of Metals members showed that metals marketing was about evenly divided between ferrous and non-ferrous metals. Stainless steel was most common among ferrous metals whereas aluminum was tops among non-ferrous.

From the average monthly amount

of 2861 gallons of cutting fluids purchased per plant in the survey, if we calculated that *all* plants represented by *all* members of the American Society of Metals might consume 12 million gallons of cutting fluid per month. If we assume a 2 percent concentration of sulfur-chlorine additive we are considering a total annual additive consumption of about 25 million pounds by ASM-represented plants alone. Conceivably this figure could be twice as large for the entire country or 50 million pounds representing gross annual sales of about $12.5 million.

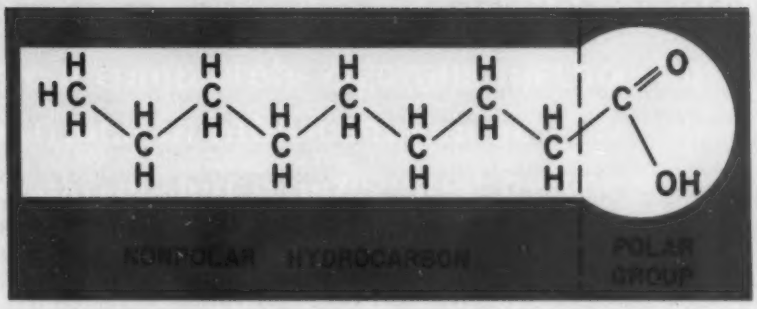

FIGURE 1—A typical additive has a hydrocarbon tail and a polar head.

Until recently research into principles of the metal cutting process have been obscured by the great maze of uncontrolled variables. Some progress has been made which shows principally that efficient cooling by the cutting fluid is one of its main functions. The application of rust preventive and lubricity additives has extended the use of water as coolant for metal-working operations so that water-based emulsions and coolants are displacing some of the oil-based fluids. However, the presence of the water permits bacteria to grow, with development of putrid odors and, in some cases bacteria actually promote rusting of finely machined ferrous metals. It has been necessary to look for new germicides. Since these bacteria are usually harmless, man hasn't spent much time and effort on finding ways to kill or inhibit them.

It is difficult to even hazard a guess on additive sales for these products especially since their history is short and their use is expanding rapidly. But let's go all out and say that 30 million gallons of water-based products and one million pounds of bactericides are sold annually, representing a total of about $10 million worth of additives.

Road Oils. About 14 million tons of road oils, cutback asphalts and penetration grade asphalts are used annually in the U.S. The primary use of these products is for surfacing highways and airport runways. Because asphalts cannot be satisfactorily applied to wet aggregates, wet weather frequently limits the time available for construction. Roads made under adverse conditions often must be rebuilt. Although wet aggregate can sometimes be dried prior to use, severe stripping of the asphalt from the stone may occur in the event of rainfall on an uncured road mat.

In 1937, McLeod[1] showed that the addition of sodium oleate—soap—to liquid asphalts enabled them to preferentially coat wet alkaline aggregates, such as limestone, and also wet acidic aggregates, such as gravel, if they are pretreated with an activator. Several additives are now commercially available; some are effective on all types of wet aggregate without pretreatment.

Use of asphalt emulsions is an expanding sales outlet for asphalts. Emulsions are made from cutback asphalts or solid grades and are applied where it is not practical to heat the asphalt prior to application. This is becoming increasingly popular for highway construction and maintenance, protective coatings, acoustical control, insulations, soil stabilization, mastics, caulking compounds and adhesives.

Rubber and epoxy resins are now incorporated with asphalts for use in such applications as airport runways and pipeline coatings. Epoxy-asphalt combinations are said to withstand fuel spillage as well as the heat of jet plane blasts.

Amounts of anti-strip additives are estimated at 3000 tons per year at an estimated cost of $1.2 million. Emulsifiers amount to about 30,000 tons at a value of only about $2 million. With the ever-increasing applications for asphalt, expanded use of additives is assured.

Waxes. Most of the 1½ billion pounds of petroleum wax produced today is used for coating packaging materials such as bread wrappers, frozen-food packages and milk cartons. Depending upon the usage, some wax products require antioxidants.

Waxed papers, formerly used only to preserve food quality, now must also add sales appeal to the wrapped article. For this reason, a glossy waxed paper is preferred to one that is dull or lusterless.

Paraffin wax used in paper coating consists of paraffinic, isoparaffinic and cycloparaffinic hydrocarbons. This hydrocarbon mixture will retain its gloss if the highest melting component is essentially linear or paraffinic in its structure, but if it is branched, irregular crystal patterns will form that are susceptible to oxidation with resulting dulling of the surface.[8] The gloss may be stabilized either by removing the high melting branched chain material, or by adding an essentially linear compound that has a higher melting point than any component of the wax. These additives are high-melting, essentially straight-chain paraffins and polymers.

It is estimated that 50,000 tons of additives for wax are used per year. The value of this amount of additive material is about $30 million. Since wax demand will soon exceed supply, some of the materials now used as additives will be used in larger amounts as extenders.

Greases. Lubricating greases consist of liquid lubricants thickened to semi-solid structure by minor amounts of dispersed solids. Service conditions dictate the choice of both ingredients; the liquid may be a petroleum oil or synthetic oil-like esters or silicones; the thickener may be soap or other dispersible solids.

During the past decade, three factors accelerated the development of thickeners other than soap: the capabilities of soaps have been rather thoroughly exploited; extensive knowledge has been gained on the structure of grease and on the role of the thickener; and increasingly severe requirements are being imposed on grease—particularly those for military uses.

Soap greases have kept pace with changing needs to an amazing degree. Improved stability or better mechanical properties were obtained with thickeners made from fatty acids of selected composition; notable examples are high-molecular-weight fish acids and hydroxy stearic acid from castor oil. Soaps of barium, strontium, or lithium combined the separate advantages of the older calcium and sodium soaps; by last year lithium greases had captured 28 percent of the U.S. market. Nevertheless, soap greases could not be expected to meet every need, and it was necessary to seek other thickeners.

The development of other grease thickeners was hastened by new knowledge of the physical nature of grease. Of primary importance were studies that demonstrated the particulate nature of the thickener. Because the oil can be removed with solvents, and even replaced without destroying the structure, the thickener must form a discrete phase.[4] During flow, greases decrease in viscosity because thickener particles orient, as can be shown by polarized light. Finally, the electron microscope yielded direct evidence of the particle size and shape.[5] Thus, we have learned that oils can be thickened to semi-solid structure by any randomly dispersed, finely divided, particulate solid. Whether or not the result is a grease depends on other properties.

Particles that thicken by sheer volume give semi-solids that have the properties of a paste rather than a grease. The difference seems to involve forces of attraction among the particles and with the oil—a characteristic called oleophilic nature." Physical bonding of very small particles to form fibers or of fiber intersections to form weak networks may explain thickening by small particles and the apparent recovery or "healing" of such networks after shearing.

The properties required in a good thickener may be deduced from our knowledge of grease structure and the new performance needs. It must exist as a separate, chemically inert phase, yet provide interaction with such a wide variety of fluids as petroleum oils, esters, and silicones. It must disperse into particles in the range of 0.01 to 20 microns. It must maintain these conditions during storage, mechanical action, and temperature over a large part of the range of —100° to 500° F, even in the presence of water.

Many compounds have been studied as grease thickeners. In chemical structure, they range from linear compounds that look like soaps to complicated ring structures that do not. Some are entirely organic in nature; others are mostly inorganic. The physical structure also varies widely. Several have the long twisted fibrous form characteristic of soaps. One consists of needles, another of platelets, and still others of irregular spheres. This variety indicates that many approaches have been used to obtain three prime properties: oleophilic nature, particle size, and thermal and chemical stability. Often one or two of these are intrinsic properties of the starting material. The others must be built into the finished thickener.

Thickeners tend to be oleophilic if their chemical structure resembles that of the oil. Such character can be built into thickeners in two ways. Inorganic particles can be coated with an oleophilic layer by chemical reactions or by physical means. Oleophilic groups can be added to organic molecules.

When greases are used under conditions requiring resistance to nuclear radiation, both the thickener and the oil must be carefully selected. Aromatic thickeners are more resistant than others, the terephthalamates having been specifically developed for this purpose. Indanthrenes and aryl ureas are also satisfactory.

Although non-soap greases now account for less than 10 percent of the U.S. market, they are doing lubrication jobs not possible 10 years ago. They are usually used either in multipurpose greases made with petroleum oil or in special high temperature greases made with synthetic oil. The significance of the terms "multipurpose" and "high temperature" is continually changing to meet new demands and developments, but the current temperature ranges are 0° to 200° F and —65° to 500° F, respectively.

For multipurpose greases, the generally improved properties of non-soap thickeners make them ideal. High melting point materials such as preformed clay, silica and urea varieties are available that cost little more than soaps.

High temperature greases are a more-specialized field, the requirements of which tax the performance of both oil and thickeners. Because the temperature range requires esters, silicones or other expensive oils, costlier thickeners can be justified.

If we consider the thickening agent in the additive picture for greases, the total percentage then approximates 10 percent of the product. In 1956 and 1957 the annual lubricating grease sales averaged 600 million pounds and about $100 million. The additive-thickener portion of this business would amount to about 60 million pounds and $20 million. Continued technological advances and improvements will undoubtedly bring new and better grease products to be used in more critical applications.

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For the first time a completely rigorous method for stagewise calculations in multicomponent fractional liquid extraction is presented by the extraction expert himself, Dr. Edward G. Scheibel. This complete report covers a review of the correlations and predictions of liquid distribution data—plus Scheibel's new method of correlation.

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Now, a new method to . . .

Figure Multicomponent Extraction

Edward G. Scheibel
York Process Equipment Corporation
West Orange, N.J.

A COMPLETELY rigorous method for stagewise calculations in a fractional liquid extraction process is described and illustrated using a newly developed correlation. The correlation is particularly applicable to the calculation technique, but any simpler or more complex representation of liquid distribution data could be used in the same method of stagewise calculations.

The method was applied to the design of a refining unit to separate the aromatics and paraffins in a reformate fraction. It was shown that a very wide boiling

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fraction could be charged to a unit depending mainly upon extraction to achieve the desired separation as compared to a relatively narrow fraction when extractive distillation is used to separate the aromatics and paraffins. The study indicates that a more economic operation can be obtained by providing a larger number of extraction stages to give the complete separation in the extractor and thus suggests that greater emphasis be placed on the liquid extraction phase of the Udex process and less on the extractive distillation portion of the process.

A complete review of the correlation and prediction of liquid distribution data and a method for developing a thermodynamically consistent correlation of liquid distribution data are presented. Based on the assumption that activity coefficients are functions only of solvent concentration, a general correlation has been developed which is applicable to multicomponent fractional liquid extraction calculations. The limitations of the assumption are discussed, and methods are described for making it more closely applicable to a particular system.

Compare Liquid Extraction with Distillation

Liquid extraction has been finding increasing applications in the refining of petroleum fractions. These fractions generally consist of a wide range of components, and the application of known calculation techniques necessitates several simplifying assumptions which leave the final solution subject to considerable uncertainty. In this respect in petroleum refining, fractional liquid extraction processes have not kept pace with the analogous fractional distillation processes.

In distillation forty odd years elapsed between the time that Sorel[13] first proposed the rigorous fundamental basis for the calculation of fractional distillation in 1893 and until the technique was applied to multicomponent distillation calculations. One important milestone in this progress was the assumption proposed by McCabe and Thiele[8] that the vapor and liquid quantities in a distillation column could be assumed constant on all the trays above the feed and on all the trays below the feed. This gave a better understanding to the mechanism of fractional distillation and paved the way for further development. Calculation techniques were ultimately developed which were rigorous and did not require the simplifying assumption. However, the assumption is sufficiently accurate so that most multicomponent calculations are presently carried out on this basis. The analogous assumption *cannot* be applied to fractional liquid extraction calculations with the same degree of reliability.

The most important milestone in the development of multicomponent fractional distillation calculations was the correlation of equilibrium data as K-values based on recognizing that hydrocarbon mixtures were very nearly ideal under the normal operating conditions of the distillation equipment, and thus Raoult's law and Dalton's law could be applied. Correlations of the K-values of the different hydrocarbons were published about forty years after Sorel's statement of the rigorous requirements for fractional distillation design, and the application of his method to multicomponent distillation followed very closely upon the publication of the vapor liquid equilibria relationships.

With liquid extraction equilibria data, it is *not* possible to make the same assumption, and assumptions finally made cannot carry the same degree of reliability as Raoult's law and Dalton's law. The first law assumes ideality of the liquid and the second assumes ideality of the vapor. In liquid extraction neither liquid phase can be considered ideal, and the separation of components is possible only because of the different degrees of the deviations from ideality.

Fractional liquid extraction calculations therefore require assumptions of the regularity of the deviations from ideality for the different components of the mixture. These deviations are expressed as activity coefficients, and before developing their correlations from multicomponent liquid distribution data, it will be desirable to review past attempts to predict liquid distribution data from activity coefficients determined on simpler systems.

Predict Liquid Distribution Data Graphically

All the early attempts to predict liquid-liquid equilibria were based on a treatment of the vapor-liquid equilibria for binary systems and assumed different variations for the activity coefficient across the range of the ternary diagram. The methods are exact for completely immiscible solvents but predict different distribution curves as the mutual solubility increases. Thus the methods can be best evaluated based on the agreement with the experimental data at high solute concentrations in the region of the plait point.

For a review of nonideal vapor-liquid equilibria a number of references 1, 2, 4, 18 are available. Vapor-liquid equilibria correlations are usually based on the activity coefficient, γ, which is a dimensionless proportionality constant measuring the deviation from Raoult's Law. Thus for any component

$$p = \gamma P x = p' = \gamma' P x' \qquad (1)$$

where p = partial pressure of the component in one liquid phase

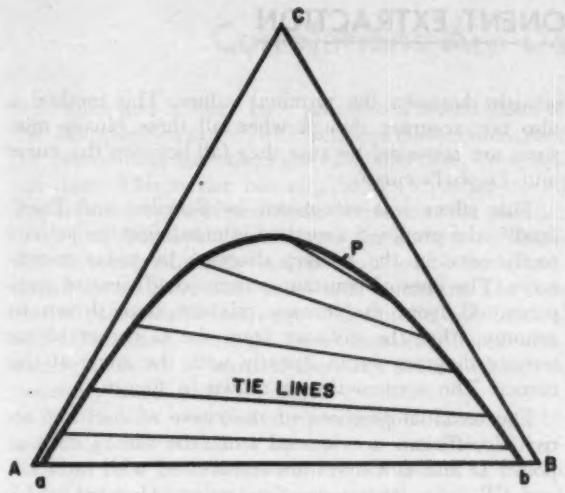

FIGURE 1—Typical ternary diagram shows mutual solubility and equilibrium tie-lines.

p' = partial pressure of same component in the other liquid phase

x = mole fraction of the component in liquid phase of partial pressure, p

x' = mole fraction of same component in other liquid phase

From Equation (1) the basic relationship for liquid-liquid equilibria data evolves:

$$\gamma x = \gamma' x' \qquad (2)$$

The product of the activity coefficients and the concentrations, γx, is called the activity. When two phases are in equilibrium the activities of a component from each of the phases must be equal.

A typical phase diagram is shown in Figure 1 for a ternary system in which components A and B are the solvents which are only slightly miscible with each other, and component C is the solute which is completely miscible in all proportions with both A and B. The mutual solubility curve is given by the curve **pPb**, and any composition inside this envelop will separate into two phases. The compositions of each of these phases are connected by a straight line which is called a tie-line. Any composition along such a line will separate into two liquid phases of the same individual compositions but in different quantities depending upon the original composition. The tie lines follow a consistant trend up to the plait point, P, at which point both phases become identical.

When the activity coefficients for component C out of mixtures with A and out of mixtures with B have been determined, the activities of component C from each of these solvents can be calculated as shown in Figure 2. Lines of constant activity will establish the equilibrium concentrations in each phase, and these values may be plotted as the distribution curve, shown in Figure 3. This was the assumption originally proposed by Hildebrand,[5] which totally ignores the effect of the mutual solubility of the solvents. It is the simplest technique to apply and gives best results with the more immiscible solvents. Since this method was first described in 1936, several other methods have been suggested to allow for the partial miscibility of the solvents.

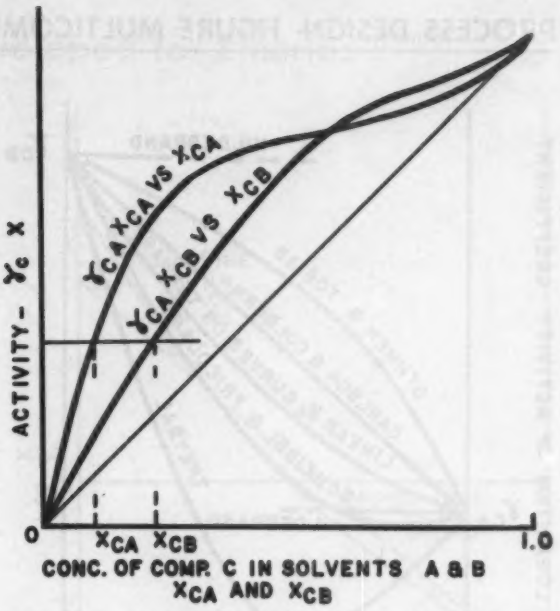

FIGURE 2—Liquid equilibrium data can be obtained from an activity-concentration diagram.

A method based on the partial pressure of a solute at different concentrations from each of the two immiscible solvents was proposed by Othmer and Tobias.[9] They assumed that the partial pressure of C from ternary mixtures varies linearly between the two terminal values along a line of constant concentration of C which is parallel to the AB side or base of the triangle in Figure 1. This and the subsequent methods can be compared by considering a plot of the activity coefficient for C along such a line as shown in Figure 4. Hildebrand's assumption corresponds to the two hori-

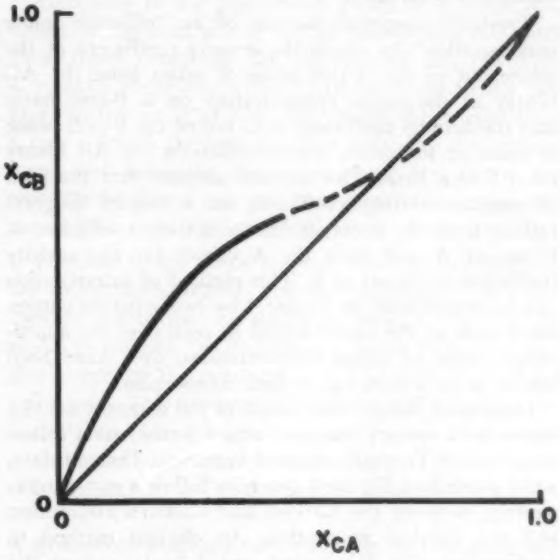

FIGURE 3—A typical liquid distribution curve may look like this one.

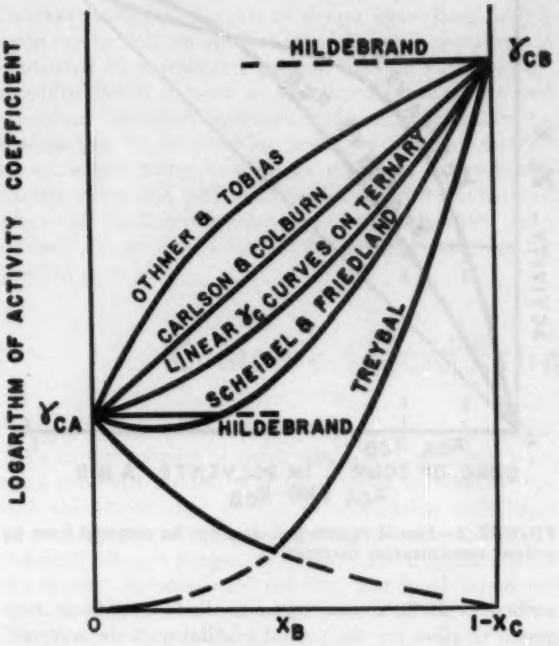

FIGURE 4—Compare various methods of predicting activity coefficients.

zontal lines from the terminal values of γ_{CA} and γ_{CB}. The Othmer and Tobias assumption is represented as a curve concave downward when the lagorithm of the activity coefficient is plotted as in Figure 4.

Carlson and Colburn[1] suggested interpolating the log γ_C linearly on this type of plot, and their method is shown by a straight line. Its application was subsequently demonstrated by Colburn and Schoenborn[3] to predict ternary vapor-liquid equilibria data from the data on the binaries.

Treybal[17] suggested the use of an "effective solute concentration" by which the activity coefficient of the solute out of the A-rich phase is taken from the AC binary at the solute concentration on a B-free basis, and the activity coefficient of C out of the B-rich phase is taken at the solute concentration in the AB binary on a C-free basis. This method assumes that the lines of constant activity coefficient on a ternary diagram radiate from the B corner for the activity coefficient of C out of A and from the A corner for the activity coefficient of C out of B. This method of interpolation can be represented on Figure 4 by two separate curves. Since each of the curves would be used over the appropriate range of solute concentrations, they have been shown as solid lines up to their intersection.

In spite of the peculiar shape of the constant activity curves on a ternary diagram, actual ternary data follow the trend of Treybal's assumed variation. Ternary data, when plotted on Figure 4 generally follow a curve intermediate between the Carlson and Colburn assumption and the Treybal assumption. An obvious method to predict curves in this region would be to assume the constant activity curves on a ternary diagram to be straight between the terminal values. This method is also not accurate though when all three binary mixtures are non-ideal because they fall between this curve and Treybal's curve.

This effect was recognized by Scheibel and Friedland[12] who proposed a method interpolating the activity coefficients on the ternary diagram by polar coordinates. The lines of constant activity coefficient of component C from the ternary mixture were drawn by assuming that the distance from the C corner of the ternary diagram varies linearly with the angle at this corner. The construction is shown in Figure 5.

The terminal positions of the curve of constant activity coefficient are located from the binary data at points D and E. Curves are constructed with radii CR and CE, and one intermediate point is located by bisecting the angle at C and locating F midway between the two arcs. Bisecting each of the two smaller angles at C will usually suffice to construct the curve of constant activity coefficient. The curves thus drawn will give a trace on the plane of Figure 4 which lies close to the actual data.

The technique was demonstrated to predict the liquid distribution data on six known systems and gave excellent agreement with the observed data. However, like all previous methods, it is empirical and therefore can only be considered approximate. No empirical method can be expected to give as good agreement with the data over an extrapolated range of conditions as a thermodynamically sound correlation. Thus, the considerably greater amount of work necessary to develop the thermodynamic data adhere to a smooth curve. On the other hand, if the basic equations for the ternary system is justified when the basic data scatter appreciably so that a smooth curve cannot be drawn through them, the simple emprical approach may be within the limits of accuracy.

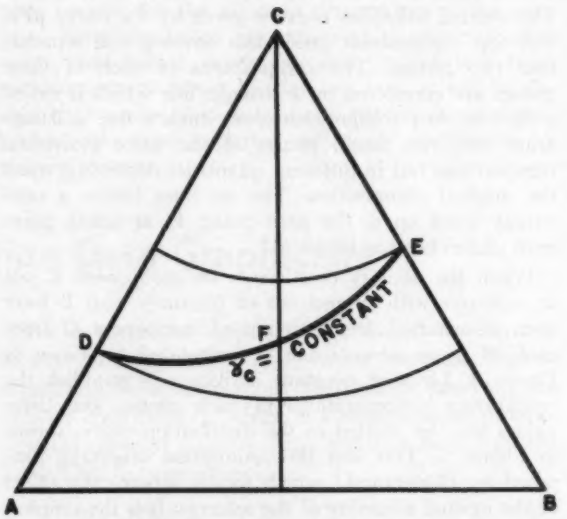

FIGURE 5—This method is suggested to predict the variation in activity coefficients.

Correlations Are Developed for Binaries

Redlich and Kister[10] have proposed a modification of the Margules equation which is especially convenient for determining the numerical constants from the original data. This writer has applied the equation to all the different types of nonideal systems over the past ten years and found that in all cases the activity coeffients for thermodynamically sound data could be represented by no more than three such constants. The successive constants were always of decreasing significance, and in no cases were the basic data considered sufficiently accurate to warrant the more precise treatment necessary to develop additional constants.

The Redlich and Kister equation was developed by assuming the excess free energy of a system to be represented by a general equation in a variable of $1 - 2x$ which varies from $+1$ to -1 over the full range of values of x. This was found to give a convenient expression of the final equations. The significance of the constants can be seen from the equation for the excess free energy of a binary mixture.

$$Q = x_1 (1 - x_1) [B_{12} + C_{12} (2x_1 - 1) + D_{12} (2x_1 - 1)^2 + \ldots] \quad (3)$$

When the variable x_1 is replaced by x_2 in a binary mixture, the equation becomes:

$$Q = x_2 (1 - x_2) [B_{21} + C_{21} (2x_2 - 1) + D_{21} (2x_2 - 1)^2 + \ldots] \quad (4)$$

the equation will be identical if

$$B_{12} = B_{21}\ C_{12} = -C_{21}\ D_{12} = D_{21}, \text{ etc.}$$

Thus when the final equations for the activity coefficients are developed, the sign of the coefficients of the odd power terms must be changed on interchanging the subscripts.

When the four suffix Redlich and Kister equations for a binary system are reduced to the Margules form, they become:

$$\log \gamma_1 = x_2^2 [B_{12} - C_{12} + D_{12} + (4C_{12} - 8D_{12}) x_1 + 12D_{12} x_1^2] \quad (5)$$

$$\log \gamma_2 = x_1^2 [B_{21} - C_{21} + D_{21} + (-4C_{21} - 8D_{21}) x_2 + 12D_{21} x_2^2] = x_1^2 [B_{12} + C_{12} + D_{12} + (-4C_{12} - 8D_{12}) x_2 + 12D_{12} x_2^2] \quad (6)$$

The constants can be determined from a suggestion by Redlich and Kister to consider the values of the log γ_2 at several preselected values of x where the function reduces to a simpler form. The present writer has developed a graphical method for determining the best values of the constants from the original data. The vapor liquid equilibria data of Tongberg and Thouston[16] on the n-hexane and benzene system will be used to demonstrate this technique.

Figure 6 shows the variation of the log $\frac{\gamma_1}{\gamma_2}$ with x_1 for this system with n-hexane taken as component 1. Redlich and Kister[10] have shown that the total area between the curve and the x axis must be algebraically

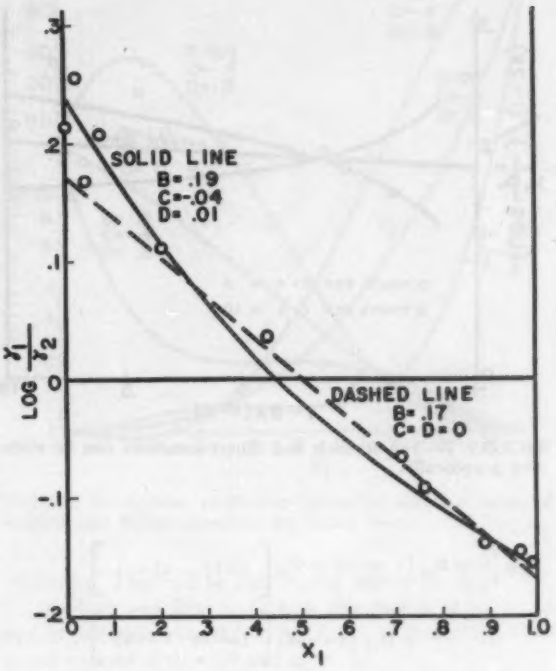

FIGURE 6—The new method of correlation shown by the dashed lines gives an excellent fit with the exception of data for low values of x.

equal to zero so the area under the first part of the curve above zero must be equal to the area over the second part of the curve below zero. This serves as an immediate indication as to whether the data can or cannot be correlated thermodynamically.

According to the preselected points of Redlich and Kister, if the data are to be correlated using not more than three constants, the distance of the curve at $x = .2113$ above the x axis must be equal to the distance of the curve at $x = .7887$ below the x axis. Thus a curve drawn through the data satisfying this requirment and balancing the areas above and below the axis can be drawn and the best value of the constants determined from the specified points.

The data in the dilute regions, where $x = 0$ and 1.0, are frequently unreliable and scatter widely. The intermediate points covering the range about $x = .15$ to .85 would be used by the Redlich and Kister technique, and they suggested the constants $B = 0.17$, $C = D = O$ for this system. This relationship is shown in Figure 6 as the dashed line. The line gives an excellent fit of the data over the previous range but misses the data at low values of x.

A graphical method for evaluating the constants can be derived from the basic equation developed by Redlich and Kister.

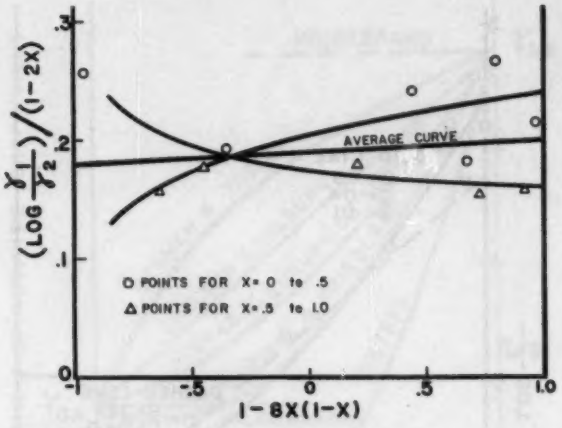

FIGURE 7—The Redlich and Kister constants can be evaluated graphically.

$$\log\frac{\gamma_1}{\gamma_2} = B_{12}(1-2x) + C_{12}\left[6x(1-x)-1\right] + D_{12}(1-2x)\left[1-8x(1-x)\right] \quad (7)$$

which can be rearranged

$$\frac{\log\frac{\gamma_1}{\gamma_2}}{1-2x} = B_{12} + C_{12}\left[\frac{6x(1-x)-1}{1-2x}\right] + D_{12}\left[1-8x(1-x)\right] \quad (8)$$

The symmetry of the equation is such that the arithmetic mean of the values of the left hand term at any value x and the corresponding value at $1-x$ will vary linearly with the function $1-8x(1-x)$ with a slope of D_{12} and an intercept B_{12}. This relationship can be utilized graphically by plotting the values of $\log\frac{\gamma_1}{\gamma_2}\Big/(1-2x)$ against $1-8x(1-x)$ as shown in Figure 7. The circles represent the data from $x=0$ to $x=0.5$, and the triangles represent the data from $x=0.5$ to $x=1.0$.

If three constants can adequately correlate the data, the curves drawn through the two sets of data must intersect at a value of $-\frac{1}{3}$ on the abscissa. Also since the coefficient of the C_{12} constant over the range of values of $1-8x(1-x)$ from $+1$ to $-\frac{1}{3}$ varies almost linearly with the abscissa, the actual data should lie along a very nearly straight line. The variation of the coefficient is such that the lines should be symmetrical and show a slight concavity toward each other. The light lines in Figure 7 have been drawn through the data to indicate this effect.

The ordinate becomes asymptotic to the abscissa value of -1 but retains the symmetry about the same straight line. A straight line drawn halfway between these curves will give the value of B_{12} at the abscissa value of zero and the value of D_{12} as the slope. The value of C_{12} is obtained from the difference between the curves and the mean line at an abscissa value of $+1$. If the curve for low values of x is above the curve for high values of x_1, C_{12} is negative. Thus for the n-hexane-benzene system, these constants are $B_{12}=0.19$, $C_{12}=-0.04$ and $D_{12}=0.01$. This technique utilized the data in the range of $x=0$ to 0.35 and $x=.65$ to 1.0. Because value of $1-2x$ approaches zero at $x=0.5$, the calculations of the function $\frac{\log\frac{\gamma_1}{\gamma_2}}{1-2x}$ becomes unreliable, and the absolute value of the $\log\frac{\gamma_1}{\gamma_2}$ is also small in the region, the deviations at the left side of Figure 7 are of little significance.

Deviations from a smooth curve in this region could best be observed on a plot similar to previous Figure 6. The heavy line on Figure 6 shows the curve calculated by the previous constants, and it will be seen that while it deviates substantially the same from the data in the center region, it gives better agreement at the ends than the equation using a single constant.

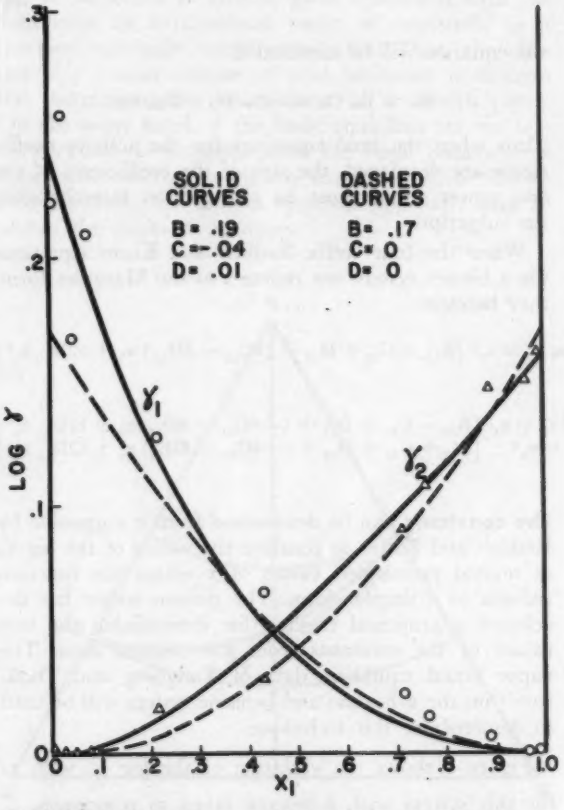

FIGURE 8—The three constant correlation gives better agreement over the entire range of data than when using one constant.

The method minimizes errors in temperature measurements since the vapor pressures of both components increase with increasing temperatures. If the vapor pressure curves on the usual semilog plots of vapor pressure against temperatures are parallel, the log $\frac{\gamma_1}{\gamma_2}$ would be independent of temperature errors. On the other hand, the individual values of γ_1 and γ_2 are dependent upon temperature. In the final analysis of the data, the individual observed values of γ_1 and γ_2 must be compared with the correlation. This is shown in Figure Eight, and it will be again noted that the individual values at $x = 0.43$ are in better agreement with the single constant correlation than the three constant correlation. On the other hand, when the entire range of data is considered, the three constants give better agreement. The largest deviations can result from an error of only 0.7% in the analyses of the vapor and liquid phases, and this is doubtless within the limits of accuracy of the original measurements.

The effect of different constants on the shape of the activity coefficient curves should be noted before proceeding with the application of the Redlich and Kister equation to liquid-liquid equilibria. When only one constant is used, the curves for γ_1 and γ_2 are symmetrical, and conversely, if the data appear symmetrical, only one constant may be necessary. On the other hand, if the data appear to give the identical intercept but follow curves different from those of the single constant the C constant is zero and only B and D are required. It can be seen from equations (9a) and (9b) that the difference between the intercepts of the log γ curves is equal to 2C and also that the value of B + D must be equal to the arithmetic mean value of these intercepts.

It is also interesting to note the effect of the relative values of the constants. If one intercept is more than twice the other or in terms of Redlich and Kister constants if D = 0 and C > (⅓) B, the activity coefficient curve having the smaller intercept must pass through a maximum, and the other curves must pass through a minimum at the same composition.

Figure 9 shows the effect of different values of D on activity coefficient curves having the same intercepts, i.e. the same values of C and of B + D. For the case of three constants, the point on the γ_1 curve at $x_1 = ⅔$ is independent of the value of D, and similarly the point on the γ_2 curve at $x_2 = ⅔$ is independent of D. Also according to the basic Gibbs Duhem equation, when one curve passes through a maximum, the thermodynamically consistent curve for the other component passes through a minimum. This can be seen in the curves for $B_{12} = 1.2$, $C_{12} = -.2$ and $D_{12} = -.4$ in the region of $x_1 = .15$ and in the curves for $B_{12} = .4$, $C_{12} = -.2$ and $D_{12} = .4$ in the regions of $x_1 = .4$ and $x_1 = .5$.

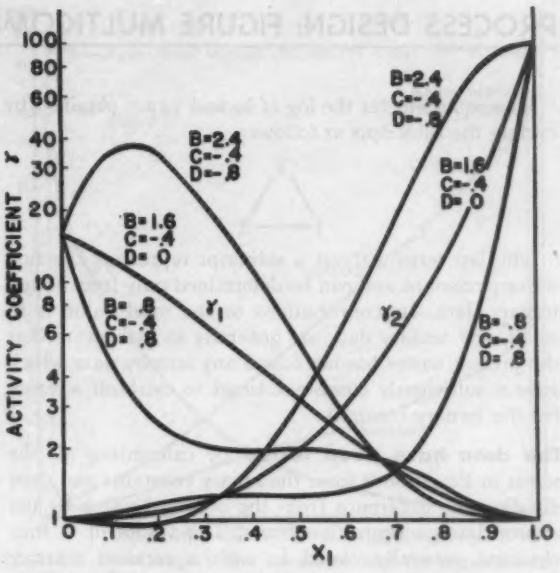

FIGURE 9—Activity coefficient curves for different values of Redlich and Kister constants are shown here.

Theoretically, any combination of constants could be introduced to give many different shapes of thermodynamically consistent curves; however, the activity coefficient curves actually encountered occur within relatively narrow limits. The constant C_{12} is generally small with respect to B_{12}, very few cases exceeding the value of ⅓ B previously mentioned. When component 1 is taken as the more volatile component, C_{12} is generally negative. Also, the D_{12} constant is generally small with respect to B_{12} and less than C_{12} in absolute numerical value. The sign of this C_{12} constant depends upon which component is designated 1.

It will be noted that the values of the D_{12} constants for the curves shown in Figure 9 are outside of the limits usually encountered in practical systems, but the extreme range has been chosen to clearly depict the effect of varying this constant. In the subsequent application of the equations to liquid distribution data, only a narrow range of concentrations will be available for developing the correlation, and in obtaining a good mathematical equation for the data, it will be useful to recognize the effect of changing the value of D to obtain a final curve of the proper shape to pass through the data.

Ternary Equilibria Can be Correlated Too

The binary Redlich and Kister constants can be applied to the calculations of the activity coefficients for ternary systems by means of the following thermodynamically sound equation:

$$\log \gamma_1 = B_{31} x_3 (1 - x_1) + B_{12} x_2 (1 - x_1) - B_{23} x_2 x_3 + C_{31} [\, 2x_3 (1 - x_1) (x_3 - x_1) - x_3^2 \,] + D_{31} [\, 3x_3 (1 - x_1) (x_3 - x_1)^2 - 2x_3^2 (x_3 - x_1) \,] + C_{12} [\, 2x_2 (1 - x_1) (x_1 - x_2) + x_2^2 \,] + D_{12} [\, 3x_2 (1 - x_1) (x_1 - x_2)^2 + 2x_2^2 (x_1 - x_2) \,] + C_{23} [\, -2x_2 x_3 (x_2 - x_3) \,] + D_{23} [\, -3x_2 x_3 (x_2 - x_3)^2 \,] + C x_1 x_3 \qquad (9)$$

The equations for the log of γ_2 and γ_3 are obtained by cycling the subscripts as follows:

The last term without a subscript represents the first ternary constant and can be determined only from actual ternary data. Its contributions to the total value is so small, and ternary data are generally so inaccurate that the present writer has not found any ternary data which gave a sufficiently consistent trend to establish a value for the ternary constant.

The data have been tested by calculating all the terms in Equation 9 from the binary constants and then dividing the difference from the observed value by the appropriate concentration terms. The values of C thus obtained generally varied in such a random manner from positive to negative values that a statistical treatment of the data would not give a value of C sufficiently different from zero to justify its inclusion in the final equation. Thus, it might be noted that the ternary data can generally be predicted from the binary data within the limits of accuracy of present analytical techniques for ternary systems.

As better data become available, it may be possible to incorporate ternary constants in the equations and even ultimately utilizing additional lower order constants, D_1, D_2 and D_3 as developed by Redlich and Kister.[10] However, for present purposes it will be assumed that the ternary data can be predicted adequately from the binary constants.

Liquid Distribution Data Can Be Predicted and Correlated by the Ternary Equations

When all three sets of binary constants are available from other sources, it is possible to calculate the activity coefficients of all components at any point on the ternary diagram. Thus, if the mutual solubility curve is determined, the variation of the activity coefficients along this curve can be calculated and plotted against solvent concentration. Selecting any point on the mutual solubility curve, the composition of the other phase in equilibrium with it can be determined by a trial and error technique similar to the dew point and bubble point calculations in multicomponent distillation.

The activity coefficients of all three components at the chosen point can be determined from the calculated curves. Then a solvent concentration of the phase in equilibrium with the specified composition can be assumed and the activity coefficients determined from the curves. The distribution coefficients are then calculated. These values are analogous to the K values in distillation and are applied accordingly. The basic relationships are given in the following equations, and they will be fully demonstrated in the process calculations on a fractional liquid extraction operation

$$D_1 = \frac{\gamma_1}{\gamma_1'} \qquad (10)$$

$$x_1' = D_1 x_1 \qquad (11)$$

and at the correctly assumed concentration of solvent

$$\Sigma x = \Sigma x' = \Sigma Dx \qquad (12)$$

where the subscripts refer to the particular component. The prime refers to the light phase, and symbols without the prime refer to the heavy phase. Thus, the analogy with distillation will be retained considering the light phase equivalent to the vapor and the heavy phase to the liquid, but since all previous derivations have been developed considering the liquid phase concentrations given by x, the term x′ had been used for the light phase concentrations instead of the conventional designation, y, used in distillation.

In most liquid extraction processes the vapor-liquid equilibria data for all the binaries are not known. Activity coefficients vary with temperature, and unless data had been determined at a suitable pressure so that the temperature agreed reasonably well with the operating temperature of the fractional liquid extraction column, some correction would be necessary before the data could be applied. Therefore, a technique has been developed to determine the Redlich and Kister constants for the ternary equations directly from liquid distribution data.

The method will be demonstrated, using the data of Johnson and Frances[6] on the n-heptane, benzene, diethylene glycol system. These authors presented the data at 75° C and at 150° C, and the data at both temperatures have been correlated by the present method. Since the commercial Udex process operates at elevated temperatures, the correlation of only the 150° C data will be discussed in this work.

Table 1 gives the composition of the phases in equilibrium expressed on a mole fraction basis, calculated from the tie line data and mutual solubility data of the previous authors.

TABLE 1—Liquid Distribution Data[6] for n-Heptane-Benzene-Diethylene Glycol System at 150° C
(Equilibrium Phase Compositions on Mole Fraction Basis)

SOLVENT PHASE			HYDROCARBON PHASE		
Heptane x_1	Benzene x_2	DEG x_3	Heptane x_1'	Benzene x_2'	DEG x_3'
.024	.013	.963	.928	.047	.025
.024	.013	.963	.925	.049	.026
.029	.028	.943	.884	.089	.027
.028	.044	.928	.785	.187	.028
.030	.094	.876	.689	.277	.034
.030	.094	.876	.620	.344	.036
.037	.203	.760	.420	.521	.059

The activity coefficients of the hydrocarbons out of the solvent were calculated from Equation 2, $\gamma = \gamma'(x'/x)$, assuming a value for γ' which will be close to unity for the hydrocarbons out of the hydrocarbon phase. The activity coefficients of the diethylene glycol (DEG) out of the hydrocarbon phase were calculated from the equivalent relationship $\gamma' = \gamma(x/x')$ assuming a value of γ close to unity for the DEG out of the solvent phase.

It is not possible from the data to determine the activity coefficients for the heptane-benzene system, and these were therefore assumed to be substantially the same as those previously correlated for the hexane-benzene sys-

tem from data of Tongberg and Thouston[16] at 67-78° C. The constants will generally be lower at the higher temperatures, but their contribution to the calculation of the coefficients for the ternary system is small, and the use of an incorrect assumption for these constants will introduce less error than the usual analytical uncertainty in the basic data. It is interesting to note in this connection that the data of Steinhauser and White[14] on the n-heptane toluene data at 100-112° C can be correlated to the Redlich and Kister constant $B_{12} = 0.120$ $C_{12} = 0.024$ $D_{12} = 0$ when heptane is taken as component 1. In general the activity coefficients of heptane out of benzene would be expected to be somewhat greater than out of toluene. The constants used in the present correlation for the ternary system were $B_{12} = 0.20$, $C_{12} = 0.04$, and $D_{12} = 0$. The true values may be lower, but they will be above the previous values for the heptane-toluene system.

These constants permitted calculation of the limiting activity coefficient of benzene out of the hydrocarbon phase, and since all the solvent systems studied by the present writer had the same general variation as shown in Figure 10, it was possible to estimate the activity coefficients of the hydrocarbons out of the hydrocarbon phase and the solvent out of the solvent phase.

It should also be noted at this point that the activity coefficient curve for benzene at low solvent concentrations could be so steep that values less than unity may be obtained from the thermodynamic equation. This decrease to values less than unity has been observed in several ternary systems reported in the literature and is therefore not unreasonable.

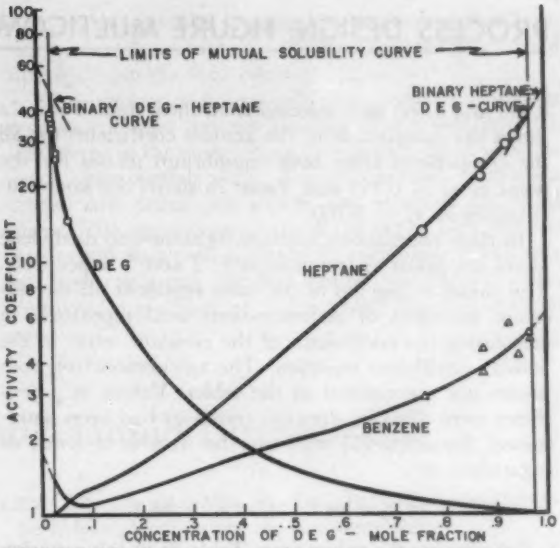

FIGURE 10—Compare the calculated and the experimental activity coefficients for the heptane-benzene-diethylene glycol system.

The preliminary calculations of the activity coefficients of the hydrocarbons out of the solvent, and the solvent out of the hydrocarbon phase are then plotted against solvent concentration on semilog plot similar to Figure 10 and curves drawn through the observed data. Observed points falling close to this curve at the limits of the data range are selected to evaluate the constants. For this purpose the points at solvent concentrations

TABLE 2a—Calculation Activity Coefficients Equations in Terms of Binary Constants in Equation 9

SOLVENT PHASE			HYDROCARBON PHASE		
	x	1—x		x′	1—x′
Heptane, x_1	.029	.971	x_1'	.884	.116
Benzene, x_2	.028	.972	x_2'	.089	.911
DEG, x_3	.943	.057	x_3'	.027	.973
	$x_1—x_2$ =	.001		$x_1'—x_2'$ =	.795
	$x_2—x_3$ =	—.915		$x_2'—x_3'$ =	.062
	$x_3—x_1$ =	.914		$x_3'—x_1'$ =	—.857

Constant	Coefficient	log γ	Constant	Coefficient	log γ′
B_{21}	.915	(1.490)	B_{21}	.003	(.005)
C_{21}	.785	(—.039)	C_{21}	—.006	(.000)
D_{21}	.670	(.060)	D_{21}	.008	(.001)
B_{12}	.027	.005	B_{12}	.010	.002
C_{12}	.000	.000	C_{12}	.024	.001
D_{12}	.000	.000	D_{12}	.032	.000
B_{23}	—.026	(—.024)	B_{23}	—.002	(—.002)
C_{23}	.048	(.020)	C_{23}	.000	(.000)
D_{23}	—.066	(—.018)	D_{23}	.000	(.000)
		$\log \gamma_1$ = (1.494)			$\log \gamma_1'$ = (.007)
B_{12}	.028	.006	B_{12}	.805	.161
C_{12}	—.001	.000	C_{12}	.500	—.020
D_{12}	.000	.000	D_{12}	.287	.000
B_{23}	.915	(.851)	B_{23}	.025	(.023)
C_{23}	—.783	(—.321)	C_{23}	.004	(.002)
D_{23}	.67	(.181)	D_{23}	.000	(.000)
B_{31}	—.027	(—.044)	B_{31}	—.024	(—.039)
C_{31}	—.050	(.003)	C_{31}	.041	(—.002)
D_{31}	—.068	(—.006)	D_{31}	—.053	(—.005)
		$\log \gamma_2$ = (.670)			$\log \gamma_2'$ = (.120)
B_{23}	.002	(.002)	B_{23}	.087	(.081)
C_{23}	—.004	(—.002)	C_{23}	.003	(.001)
D_{23}	.003	(.001)	D_{23}	.000	(.000)
B_{31}	.002	(.003)	B_{31}	.860	(1.402)
C_{31}	.004	(.000)	C_{31}	—.691	(.035)
D_{31}	.006	(.001)	D_{31}	.552	(.050)
B_{12}	—.001	.000	B_{12}	—.079	—.016
C_{12}	.000	.000	C_{12}	—.125	.005
D_{12}	.000	.000	D_{12}	—.149	.000
		$\log \gamma_3$ = (.004)			$\log \gamma_3'$ = (1.558)

TABLE 2b—Calculation of Activity Coefficient Equations in Terms of Binary Constants

SOLVENT PHASE			HYDROCARBON PHASE		
	x	1—x		x′	1—x′
Heptane, x_1	.037	.963	x_1'	.420	.580
Benzene, x_2	.203	.797	x_2'	.521	.479
DEG, x_3	.760	.240	x_3'	.059	.941
	$x_1—x_2$ =	—.166		$x_1'—x_2'$ =	—.101
	$x_2—x_3$ =	—.557		$x_2'—x_3'$ =	.462
	$x_3—x_1$ =	.723		$x_3'—x_1'$ =	—.361

Constant	Coefficient	log γ	Constant	Coefficient	log γ′
B_{21}	.732	(1.193)	B_{21}	.034	(.056)
C_{21}	.480	(—.024)	C_{21}	—.029	(.001)
D_{21}	.310	(.028)	D_{21}	.016	(.001)
B_{12}	.196	.039	B_{12}	.302	.060
C_{12}	—.024	.001	C_{12}	.211	—.008
D_{12}	.003	.000	D_{12}	—.052	.000
B_{23}	—.154	(—.143)	B_{23}	—.031	(—.029)
C_{23}	.172	(.071)	C_{23}	—.028	(—.012)
D_{23}	—.144	(—.039)	D_{23}	—.020	(—.005)
		$\log \gamma_1$ = (1.126)			$\log \gamma_1'$ = (.064)
B_{13}	.030	.006	B_{12}	.201	.040
C_{13}	—.011	.000	C_{12}	—.217	.009
D_{13}	.002	.000	D_{12}	.045	.000
B_{23}	.606	(.564)	B_{23}	.028	(.026)
C_{23}	—.099	(—.041)	C_{23}	.030	(.012)
D_{23}	—.079	(—.021)	D_{23}	.021	(.006)
B_{31}	—.028	(—.046)	B_{31}	—.025	(—.041)
C_{31}	—.041	(.002)	C_{31}	+.018	(—.001)
D_{31}	—.044	(—.004)	D_{31}	—.010	(—.001)
		$\log \gamma_2$ = (0.460)			$\log \gamma_2'$ = (.050)
B_{23}	.049	(.046)	B_{23}	.491	(.456)
C_{23}	—.095	(—.039)	C_{23}	.182	(.075)
D_{23}	.091	(.025)	D_{23}	.064	(.017)
B_{31}	.009	(.015)	B_{31}	.395	(.645)
C_{31}	.014	(—.001)	C_{31}	—.109	(.005)
D_{31}	.016	(.001)	D_{31}	.027	(.002)
B_{12}	—.008	—.002	B_{12}	—.219	—.044
C_{12}	.003	.000	C_{12}	.044	—.002
D_{12}	.000	.000	D_{12}	—.007	.000
		$\log \gamma_3$ = (.045)			$\log \gamma_3'$ = (1.154)

0.943 and 0.760 were selected from these data. Table 2a shows the calculations of the activity coefficients for all the components from both equilibrium phases for the point at $x_3 = 0.943$ and Table 2b shows the same calculations at $x_3 = 0.760$.

In these correlations, heptane, benzene and diethylene glycol are taken as components 1, 2 and 3 respectively. The values at the top of the table represent all the different functions of concentrations used repeatedly in calculating the coefficients of the constant terms in the activity coefficient equation. The calculations for both phases are summarized in the tables. Values in parentheses were filled in after the constants had been determined. Equation (2) may also be written in terms of logarithms as:

$$\log \gamma_1 - \log \gamma_1' = \log x_1' - \log x_1 \qquad (2a)$$

Substituting the values from Table 2a in this equation gives for log γ_1

$$.912\ B_{31} + .791\ C_{31} + .662\ D_{31} = 1.486 + .024\ B_{23} - .048\ C_{23} + .066\ D_{23} \qquad (13)$$

and for log γ_2

$$.890\ B_{23} - .787\ C_{23} + .670\ D_{23} = .637 + .003\ B_{31} + .091\ C_{31} + .015\ D_{31} \qquad (14)$$

and for log γ_3

$$.858\ B_{31} - .695\ C_{31} + .558\ D_{31} = 1.554 - .085\ B_{23} - .007\ C_{23} + .003\ D_{23} \qquad (15)$$

The same calculations for the point at $x_3 = 0.760$ gives the equations:

for log γ_1

$$.698\ B_{31} + .509\ C_{31} + .294\ D_{31} = 1.067 + .123\ B_{23} - .200\ C_{23} + .124\ D_{23} \qquad (13a)$$

for log γ_2

$$.578\ B_{23} - .129\ C_{23} - .100\ D_{23} = .450 + .003\ B_{31} + .059\ C_{31} + .034\ D_{31} \qquad (14a)$$

and for log γ_3

$$.442\ B_{23} + .277\ C_{23} - .027\ D_{23} = 1.154 - .386\ B_{31} + .123\ C_{31} - .011\ D_{31} \qquad (15a)$$

The numerical values in these equations can also be adjusted for the deviation of the particular experimental point from the average curve, and in this case the experimental value for log γ_2 at $x_3 = 0.943$ was 0.045 below the average curve through the data. Therefore, the numerical value on the right-hand side of Equation 14 was increased to 0.682 before solving the equations.

These relationships consist of six linear equations in six unknowns and could be solved by standard algebraic technique. However, they have been rearranged to combine the terms contributing least to the total value with the constant and can thus be treated as two sets of equations in three unknowns by assuming a value of the B constants on the right equal to the intercept of the original average curves drawn through the data and neglecting the C and D constants on the right. Inspections of these equations reveals that Equation (15a) will have the greatest uncertainty by this technique because of the relatively large coefficient of the B_{31} term on the right. Thus, the calculations were started assuming $B_{23} = 0.8$.

Solving the three Equations (13, 14, 15) for the (31) constants on the left gave values of $B_{31} = 1.72$, $C_{31} = -.05$, and $D_{31} = -.03$. Substitution of these values in the left-hand sides of the remaining equations in the (23) constants, and solving for the remaining constants gave values of $B_{23} = 0.90$, $C_{23} = 0.33$, and $D = 0.22$. These values were then substituted in the first set of equations, which on solving gave a new set of (31) constants. Repeating the cycle, a new set of (23) constants were obtained which, when substituted in previous equations did not yield values sufficiently different to justify an additional cycle.

The trial-and-error procedure for evaluating the constants may appear more complex than solving the six simultaneous equations directly, but it will immediately disclose any peculiarities in the values of the constants and indicate the source of uncertainty. The basic data can then be inspected for choice of a better location of the average curve.

If B should be negative when the systems exhibit positive deviations as in theoretically possible when D is greater than B, the correlating curves can be considered unreliable and new ones selected through the data based on a study of effects shown in Figure 9. Actually, D is always appreciably less than B. Similarly, C is usually less than ⅓ B, and only a few cases are recorded where it is slightly greater. Thus, the general relationship between the binary constants, such that $B > C > D$, can be noted immediately by the foregoing technique.

Table 3 summarizes the constants determined for the system, and Figure 10 shows the curves calculated from these constants. A sample calculation is shown by completing Tables 2a and 2b to give the values indicated in parentheses. Figure 10 also shows the original data and indicates that they were thermodynamically consistent within the limits of accuracy of the measurements because the nonreproducibility of the original data is greater than the deviations from the theoretical curve.

The observed activity coefficients are then recalculated based on calculated activity coefficient of the diethylene glycol out of the solvent phase and the calculated activity coefficients of the hydrocarbons out of the hydrocarbon phase. Since the deviation from unity is small in all these cases, the uncertainty introduced by inaccuracies in the correlating constants is substantially negligible. For this reason, when a family of curves such as shown in Figure 10 has been deter-

TABLE 3—Redlich and Kister Constants for Heptane, (1) Benzene, (2) Diethylene Glycol, (3) System at 150° C

Binary Constants

Heptane—DEG	Benzene—DEG	Benzene Heptane
B_{31} = 1.63 C_{31} = —0.05 D_{31} = 0.09	B_{23} = 0.93 C_{23} = 0.41 D_{23} = 0.27	B_{12} = 0.20 C_{12} = —0.04 D_{12} = .0

mined, it can also be used for the preliminary calculations on similar systems involving other solvents to give the first approximation of the activity coefficients to inspect the data and to smooth it as originally discussed.

It will be seen from Table 3 that the numerical values of the constants are consistent with the experience in vapor liquid equilibria correlation. The relationship between C and D is not critical as long as both are small with respect to B, and therefore, in the present case the fact that D_{31} is greater than C_{31} is of no significance because both are so small with respect to B_{31}. It is obvious that both values are very sensitive to slight variations in the value of B since C was greater than D in the first trial calculation and the relationship reversed on improving the final solution.

The previous technique will give thermodynamically consistent curves through the two data points selected. The shape of the curves must then be compared with the actual intermediate data. Any two activity coefficient curves will define the system and establish the third curve. The agreement of the third curve with the experimental data will indicate its reliability. When this has been confirmed, the data can be applied with confidence to the design of a fractional liquid extraction process.

Predict Multicomponent's Liquid Distribution

Studies of the activity coefficients of ternary systems involving two ideal components indicate the activity coefficients are functions of the concentration of the third nonideal component and substantially independent of the relative amounts of the two ideal components in the mixture. This has been the reason for presenting the correlation of the liquid distribution data as shown in Figure 10.

The writer has correlated multicomponent liquid distribution data for several other systems on this same basis and obtained as good or better agreement with the thermodynamic curves as in the present system. Only one system failed to correlate satisfactorily, and this employed a mixed solvent.

The mixed solvent was treated in the calculations and the subsequent correlation, as a single compound, and this may not have been a reasonable assumption. It may be necessary in such cases to develop the quarternary data and apply the quarternary thermodynamic equations. Such a procedure is exceedingly complex because while the calculations may be readily made on an automatic computer, the representation of the data on suitable curves for convenient application to process design calculations may be complicated. A simple method for handling a mixed solvent in the calculations is very desirable, and as more multicomponent liquid distribution data become available, a suitable method may be developed. The present technique can be applied with greatest confidence in systems utilizing a pure solvent.

In solvents exhibiting very low mutual solubility, it can be shown that the activity coefficient of the slightly soluble constituent out of the saturated solution is very nearly equal to the reciprocal of the solubility. Thus, it may be concluded that the intercepts of the activity coefficient curves will vary with carbon number in the same ratio as the solubility of the hydrocarbons of different carbon number.

Applying this concept to the solubility data of hydrocarbons in diethylene glycol and assuming that all the constants vary in the same ratio, the following equations were developed for the aromatic hydrocarbons in the paraffin-diethylene glycol system:

$$B_{23} = 0.33 + 0.10\,n \quad (16a)$$

$$C_{23} = 0.14 + 0.045\,n \quad (16b)$$

$$D_{23} = 0.09 + 0.030\,n \quad (16c)$$

and for the paraffins in the aromatic hydrocarbon-diethylene glycol system the equations are:

$$B_{31} = 1.10 + 0.075\,n \quad (16d)$$

$$C_{31} = -0.036 - 0.002\,n \quad (16e)$$

$$D_{31} = 0.062 + 0.004\,n \quad (16f)$$

where n is the number of carbon atoms in the hydrocarbon.

These constants were used in the thermodynamic equations for the activity coefficients of the hydrocarbons along the mutual solubility curve determined for the reference system of n-heptane benzene, and the family of curves, shown in Figure 11, were obtained.

The activity coefficient of the solvent is shown as a simple curve extrapolated according to the relationship $\gamma_3 = 1/x_3$ which holds for all the higher paraffinic hydrocarbons. Using the appropriate constants calculated from Equation (16) along the mutual solubility curve for the reference system gives impossible results because with the higher hydrocarbons this solubility curve lies in the two-phase region. The curve as shown can be assumed to hold for all paraffinic hydrocarbons and γ_3 is thus a function only of solvent concentration and independent of the composition of the paraffinic and aromatic hydrocarbons.

In applying these curves the activity coefficients of the paraffins and the aromatics are assumed to be functions only of the total aromatics and paraffins in the liquid, independent of the individual compounds of each type. This assumption has been reasonably well established, however, in order to extend it to the assumption that the activity coefficients are function only of the solvent concentration it is necessary to impose one additional condition; namely, that the mutual solubility curve is independent of the composition of the paraffinic fraction.

This variation in the mutual solubility is the greatest source of uncertainty and also prevents the use of a particular correlation at other temperatures. For example, the data of the previous authors on this same system at 75° C gave activity coefficient curves with intercepts only 10% greater than at 150° C. However at the lower temperature benzene is only partially miscible

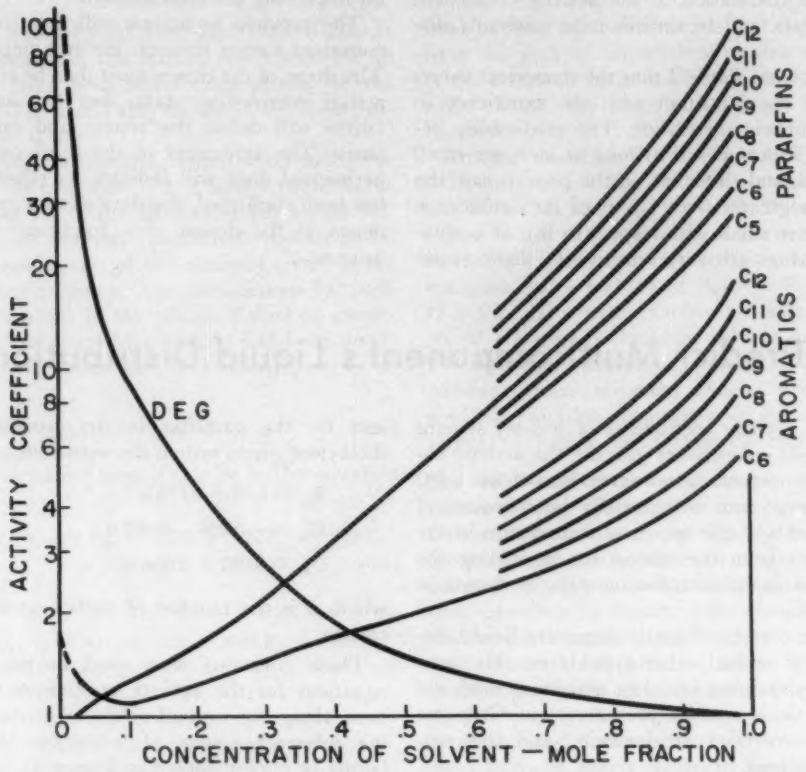

FIGURE 11—Activity coefficients for aromatics and paraffins in diethylene glycol solution are assumed to be independent of the compositions of the aromatic and paraffinic fractions.

with the solvent and the mutual solubility curve is of the open type.

The present correlation could not be applied directly but it is interesting to note that if the activity coefficient correlation were developed along the proper solubility curve the activity coefficients would have been in error by less than 10%. This indicates that when the activity coefficient correlation has been made at one temperature it can be extrapolated over a limited range to other temperatures if the mutual solubility data are determined at the new temperature.

The variation of mutual solubility with the composition of the aromatic and paraffinic fractions has also been overcome in systems involving other solvents by developing the countercurrent multistage equilibrium data for the given hydrocarbon feed using an apparatus and technique described elsewhere by the present author.[11] This technique provides the equilibrium data along a mutual solubility curve obtained by distributing the components in the countercurrent fractional liquid extration operation in a manner very similar to that which will be obtained in the final design. If the solvent ratio employed to develop the data is close to the final design ratio, there will be substantially no error introduced from this source. The correlation of the activity coefficients of the individual components will give curves similar to those of Figure 11, which can be used with complete confidence.

In the application of this technique to multicomponent data, it has been found desirable to select key components for each of the groups of hydrocarbons close to the average hydrocarbon number of the groups in the feed. The thermodynamic equations are then determined for the ternary system similar to those for the n-heptane-benzene-diethylene glycol system discussed. The effect of carbon number on the activity coefficients can then be determined from the original data according to a relationship similar to Equations (16) and the smoothed curves calculated by substituting the appropriate constants in the thermodynamic equations.

The paraffin curves are calculated changing only the (31) constants for the paraffin system and using the (23) constants for the aromatic component determined for the key aromatic component. Similarly the curves for the different aromatics are calculated using the appropriate (23) constants and using the (31) constants originally determined for the key paraffinic component.

Several correlations of this type have been developed which accurately reproduce the original data and could be used with greater confidence than the present curves, but these data have not yet been released for publication. The present curves will be adequate to demonstrate the application of the correlation to the stagewise calculations of a multicomponent fractional liquid extraction process. If data of the type previously described were to

be made available on this solvent in the future, a more reliable correlation could be developed, but it would not alter the technique for applying the correlation.

The flowsheet shown in Figure 12 is proposed for separating the aromatics from the paraffins using diethylene glycol as the selective solvent. The conventional Udex process employs an extractive distillation column to give the final purification of the aromatic components dissolved in the extract from the liquid extraction column. In the present flowsheet, the separation of the aromatics and paraffins is effected completely in the liquid extractor, and an equilibrium flash obtained by reducing the pressure on the extract serves to eliminate the light hydrocarbons dissolved in the extract for recycle to the extractor. The liquid from the flash drum is then stripped to completely remove the dissolved aromatic hydrocarbons without further fractionation between the aromatics and paraffins.

Quantities are given for some of the streams to indicate the amount handled in the different items of process equipment and thereby given an indication of the relative sizes of the individual units. The design has been based on reformate feed of 4,700 bpd which corresponds to the molar quantities assumed for the composition of the feed and product streams given by the material balance in Table 4.

The separation in the liquid extractor is specified on a depentanized basis to give 1% aromatics in the raffinate and 0.7% paraffins in the extract on a mole basis. The light pentane fraction from the reformer effluent has been found to have a high octane number and therefore suitable for inclusion in final gasoline product. If the process is to be operated to produce pure aromatic compounds, this pentane fraction can be very readily fractionated off because of its high volatility relative to the benzene fraction of the aromatic mixture.

An Example of How the Method Works

The reformate feed is stripped of the light C_5 fraction in the prefractionator. This fraction supplies some of the reflux to the bottom of the fractional liquid extraction column, and the bottoms product from the perfractionator constitutes the feed to the liquid extraction column. The solvent recycle of diethylene glycol is run into the top of the extraction column and leaves the bottom with the aromatics in the feed and saturated with the pentane fraction. The column operates at 300°F and 200 psig, and the pressure is reduced to 9 psig in a flash drum, allowing most of the dissolved pentane to evaporate off. This is condensed and recycled to the bottom of the extractor as reflux.

The liquid from the flash drum contains an amount of pentane equal to that in the feed and passes to the extract stripper where the hydrocarbons dissolved in the solvent are removed, and the stripped solvent is recycled to the extractor. The aromatic hydrocarbon mixture is washed with water to remove the last traces of solvent.

The raffinate from the fractional liquid extraction column passes to a raffinate stripper where the dissolved pentane is removed and recycled to the bottom of the extractor. The raffinate is then washed with water to remove the last traces of solvent, and it passes to the conventional treatment to prepare it for recycle to the reformer. The water streams from this wash column and the extract wash column are run to a water-solvent still where the water is fractionated off and recycled to the wash columns. The recovered solvent is returned to the solvent circulating system.

Substantially all the fractionation between the aromatics and paraffins in this process is carried out in the liquid extration column. The small amount of additional fractionation obtained by flashing off the pentane is incidental, and no further fractionation occurs after this flash drum. The extract product from this drum can be stripped vary easily from the solvent in a few theoretical trays and this makes it possible to use a vacuum distillation to minimize temperature changes of the solvent.

The solvent circulating rate of this process is greater than in the conventional Udex process but since no temperature changes are involved, the solvent circulation does not affect the over-all utilities. On the other hand, this process eliminates the extractive distillation column in the conventional process and substitutes a solvent stripper which is a small column and requires only the minimum amount of heat necessary to remove the dissolved hydrocarbons. The present process introduces a small raffinate stripper to depentanize the light product from the extractor, but this column operates at a sufficiently low reflux ratio that most of the vapor will be derived from the sensible heat of the feed.

How The Process Calculations Are Made

The over-all material balance on the extraction process is shown in Table 4. Also shown is the hydrocarbon material balance on the extraction column. The 28 moles/hr pentane recovered from the raffinate and the 14 moles/hr pentane stripped from the fresh feed to the unit are added to the flash vapor to provide the total amount of reflux to the extraction column.

TABLE 4—Material Balance on Liquid Extraction Unit
(Design Basis: 4700 BPD Reformate Feed)

	Over-All, moles/hr.			For Extractor, moles/hr.		
	Feed	Net Raffinate	Net Extract	Raffinate	Extract	Flash Vapor
Paraffins						
C_{6P}	15	1.0	14.0	29.0	244	230
C_{6P}	15	14.4	.6	14.4	5.8	5.2
C_{7P}	50	49.2	.8	49.2	4.9	4.1
C_{8P}	75	74.4	.6	74.4	2.5	1.9
C_{9P}	50	49.9	.1	49.9	.3	.2
C_{10P}	10	10.0	.....	10.0	.....	.....
Total	215	198.9	16.1	226.9	257.5	241.4
Aromatics						
C_{6A}	25	.....	25.0	.....	55.7	30.7
C_{7A}	100	.1	99.9	.1	169.9	70.0
C_{8A}	100	.4	99.6	.4	139.6	40.0
C_{9A}	50	.7	49.3	.7	62.6	13.3
C_{10A}	25	.8	24.2	.8	28.3	4.1
Total	300	2.0	298.0	2.0	456.1	158.1
Total	515	200.9	314.1	228.9	713.6	399.5
lbs./hr.	54800	22800	32000	.....	.....	.....
BPD	4700	2100	2600	.....	.....	.....

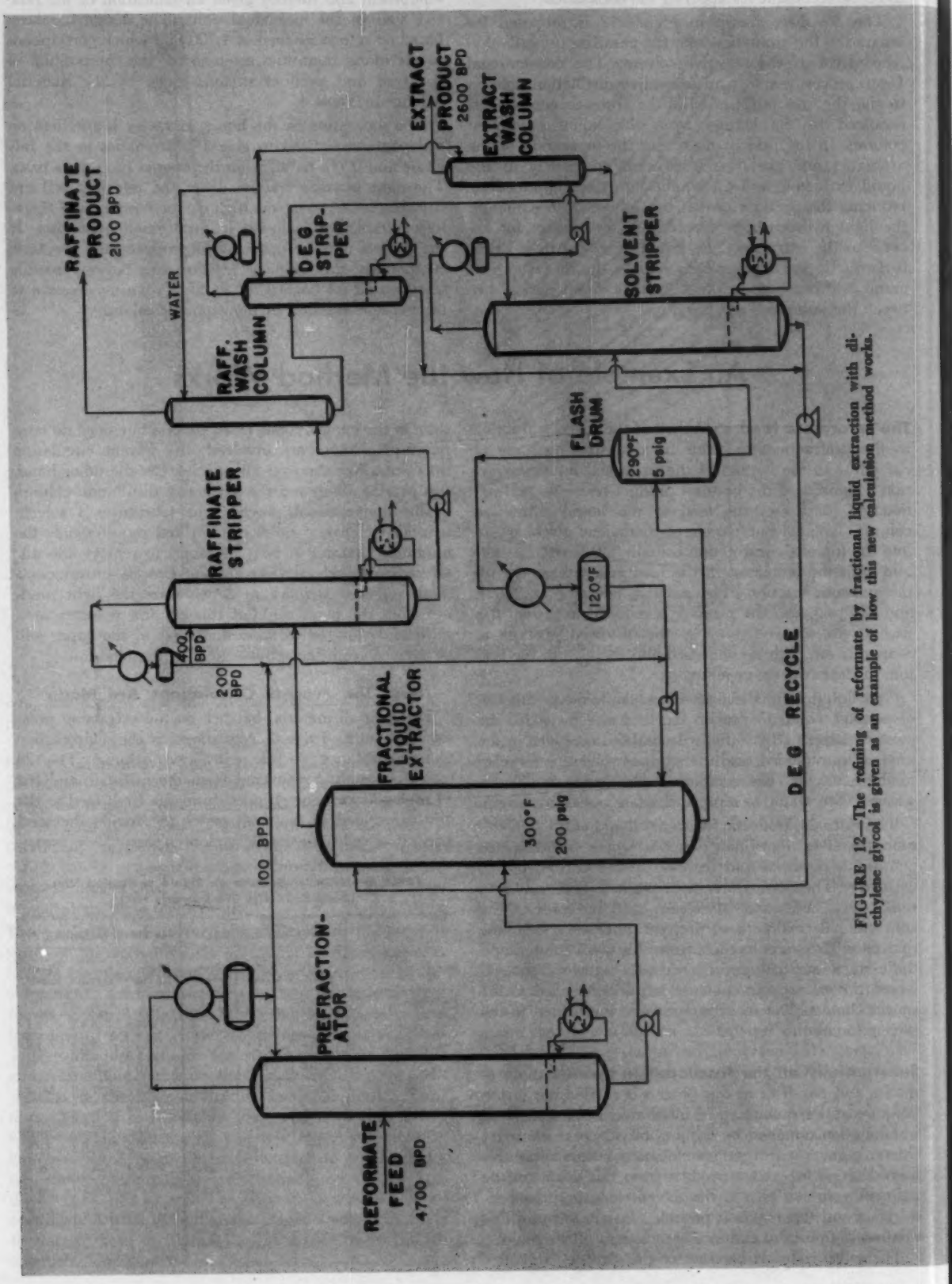

FIGURE 12—The refining of reformate by fractional liquid extraction with diethylene glycol is given as an example of how this new calculation method works.

TABLE 5—Solubility Calculation on Solvent Stream for Extraction

	SOLUBILITY CALCULATION ON SOLVENT STREAM FROM EXTRACTOR									
	Flash Liquid (Final Prod.) moles/hr.	$\gamma_{0.947}$	P 290°F	γPm	Flash Vapor moles/hr	Total Solvent Stream B-1H moles/hr.	$\gamma_{0.888}$	$\gamma'_{0.050}$	D	mD
C_{5P}	14.0	22.8	14	4460	230	244	17.5	1.24	14.1	(3430)
C_{6P}	.6	27.0	6.4	100	5.2	5.8	20.2	1.24	16.3	95
C_{7P}	.8	32.0	3.1	79	4.1	4.9	23.5	1.24	18.9	93
C_{8P}	.6	37.2	1.6	36	1.9	2.5	27.0	1.24	21.8	55
C_{9P}	.1	44.7	.82	4	.2	.3	31.8	1.24	25.7	8
C_{10P}	.....	52.0	.43	....	.....	.....	36.8	1.24	29.7	....
C_{6A}	25.0	4.68	5.1	595	30.7	55.7	3.85	1.10	3.50	195
C_{7A}	99.9	5.65	2.4	1360	70.0	169.9	4.57	1.10	4.16	707
C_{8A}	99.6	6.80	1.15	787	40.0	139.6	5.35	1.10	4.87	680
C_{9A}	49.3	8.10	.65	259	13.3	62.6	6.20	1.10	5.64	353
C_{10A}	24.2	9.60	.34	79	4.1	28.3	7.30	1.10	6.64	188
Total Hydrocarbons	314.1	.....	.....	....	....	.....	.....	.....	.....	....
DEG	5650.	1.01	.026	149	7.7	5657.7	1.04	10.3	.101	572
Total	5964.1			7908	407.2	6371.3 −244				6376
						6127				2946

Total Pressure at 290°F.

$\frac{7908}{5964} = 1.325$ atm = 5 psig.

$\frac{6127-2946}{14.1-1} = 243$ m/hr C_{5P} in solvent stream.

The quantity of flash vapor must be determined by the trial-and-error procedure illustrated in Table 5, since the solvent stream leaving the bottom of the extractor must be saturated with the hydrocarbons to be in equilibrium with the hydrocarbon phase in the extractor. The solvent rate in this process design was 5660 moles/hr. which corresponds to 8 times the hydrocarbon feed to the extractor on a volume basis.

Table 5 gives the activity coefficients for all the components out of the flash drum liquid at $x_3 = \frac{5650}{5964} = 0.947$ determined from Figure 11. The coefficients at 290°F are assumed to be the same as at 300°F. The vapor pressures of the pure components in atmospheres at 290°F are also given. The total pressure in the system is $\Sigma_\gamma Px$ and in this table is calculated as $\frac{\Sigma\, \gamma\, Pm}{\Sigma\, m}$ where the m refers to the moles per hour of each component in the flash liquid. The calculation of total pressure is given below the totals in the table and is found to be 1.325 atm. The γPm column also gives the composition of the flash vapor in equilibrium with the liquid, and it is necessary to determine the amount of this vapor which when dissolved in the solvent stream from the bottom of column will bring the solvent to its saturation point.

The calculation is very similar to a bubble point calculation in multicomponent distillation and corresponds exactly to the more accurate techniques in which the vapor and liquid fugacities are evaluated from correlations based on molal average boiling points which must first be assumed. In the present case, solvent concentrations in each phase must be assumed in order to determine the distribution coefficients which will then permit a calculation of solvent concentrations. The assumed solvent concentrations can be checked very readily before proceeding with the evaluation of the distribution coefficients of all the components by considering only the distribution coefficent of solvent. The basic requirement for saturation of a multicomponent solution is that $\Sigma x' = \Sigma Dx = \Sigma x$ which in terms of moles per hour of each component becomes $\Sigma mD = \Sigma m$ and the distribution coefficient is calculated as previously defined $D = \frac{\gamma}{\gamma'}$

In the table the solvent concentration in the heavy phrase from the bottom stage (B-1H) is calculated as $\frac{5657.7}{6371.3} = 0.888$ and at this concentration, the activity coefficient of the solvent is 1.04. If the solubility calculation is to finally check out, the total of the mD column must also be 6371.3, and thus assuming a concentration of solvent in the hydrocarbon, the value of D and then mD for the solvent can be readily calculated and the assumed value of solvent concentration immediately checked. Assuming a value of 0.05 will give $\frac{\gamma'}{.05} = 16.5$ whence D = 0.063 and mD = 366, and thus the calculated solvent concentration in the light phase is 0.056. At this concentration, the activity coefficient is 10% lower than at the previous concentration, and the trial-and-error must be continued until a better agreement is obtained. At an assumed concentration of 0.090, the deviation of the calculated concentration of 0.0898 is well within the accuracy of reading the figure.

Generally, an acceptable accuracy of 0.001 mole fraction can be achieved without excessive calculation. It might be recognized at this point that this accuracy is much greater than appears to be justified on the basis of the accuracy of the original correlation. However, carrying out the calculations to this degree of accuracy eliminates all sources of error in the calculation technique, and the final result will have exactly the same accuracy as the original correlation. No additional assumptions or approximations are introduced by the calculation technique.

The activity coefficients and the distribution coefficients of all components are then determined, and the

mD values for all components are calculated. The sum of the mD terms in the last column must total the same as the sum of the sixth column. If they do not, a new quantity of flash vapor must be assumed. The author has developed a convenient method for pin-pointing the correct value by calculating the quantity of C_{5P} in the solvent stream to bring it up to the saturation composition. Neglecting the amount of this component in both columns, the sums are shown below the final totals.

It can be seen that each mole of C_5 in the solvent phase will increase the Σ mD term by D — 1 or 13.1 units. Thus, the difference in the two totals divided by 13.1 as shown in the calculation below these columns gives a quantity of 243 moles/hr. of C_{5P} in the solvent stream. This is in excellent agreement with the assumed value of 244, and the value in parenthesis in the last column is then calculated as 243 × 14.1. The inaccuracy in the total of the last column is due to slide rule calculation, since the correct value in the parenthesis should be 3425.7.

In matching a calculated value with an assumed value, an agreement within 2% of the originally assumed value, which in this case represents an agreement within 4 moles/hr., will be satisfactory. When the calculated value of the C_{5P} quantity does not check the assumed value, the correct assumption will usually be very nearly halfway between the assumed and calculated value. Recognizing this variation, the second trial will invariably give satisfactory agreement.

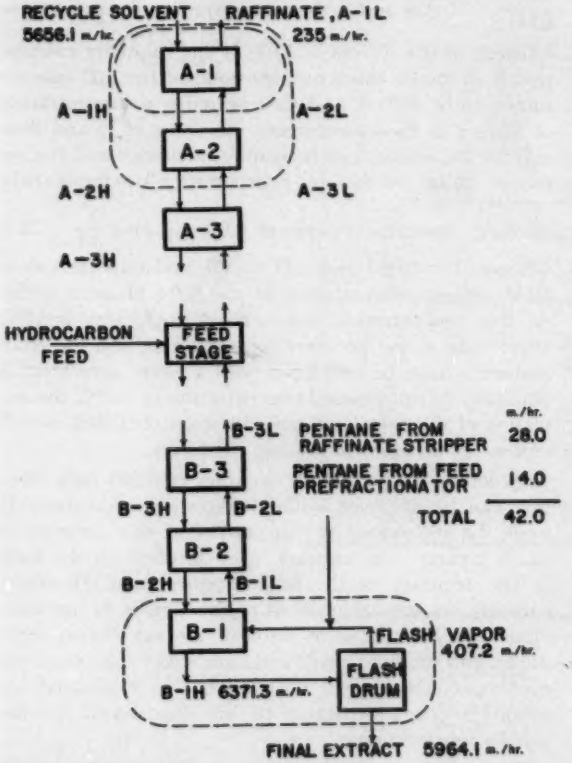

FIGURE 13—Here is a schematic diagram for the process streams in a fractional liquid extraction column.

When the composition of the extract stream from the bottom stage has been established, the stagewise calculations can be carried up the column. The first stage calculations are illustrated in Table 6. The first column shows the quantities of each component in the light phase based on an assumed quantity of 258 for the C_{5P}. The amounts in the heavy phase from the B-2 stage are calculated from the material balance around the bottom stage as illustrated graphically in Figure 13. Including the flash drum in the balance simplifies the arithmetic involved.

TABLE 6—Stage Calculation for the Bottom Stage, B-1

	Stage Calculation for the Bottom Stage, B-1					
	B-1L m/hr	B-2H m/hr	$\gamma_{.999}$	$\gamma'_{.99}$	D	mD
C_{5P}	258	230	17.6	1.24	14.2	(3220)
C_{6P}	7.1	7.7	20.5	1.24	16.5	125
C_{7P}	7.0	7.8	23.7	1.24	19.1	149
C_{8P}	4.1	4.7	27.5	1.24	22.2	104
C_{9P}	.6	.7	32.5	1.24	26.2	18
C_{10P}	.....	.....	37.5	1.24	30.2	....
C_{6A}	14.7	39.7	3.9	1.10	3.55	141
C_{7A}	53.1	153.0	4.6	1.10	4.19	641
C_{8A}	51.1	150.7	5.4	1.10	4.91	741
C_{9A}	26.5	75.8	6.3	1.10	5.73	434
C_{10A}	14.1	38.3	7.3	1.10	6.65	255
DEG	43.3	5693.3	1.04	10.3	.101	575
Total	479.6	6401.7	.....	.....	.....	6405
		—230				
		6171.7				3183

$$\frac{6171.7-3183}{14.2-1} = 226 \text{ m./hr } C_{5P}.$$

The solvent concentrations are established by the same technique previously described, and the last column is calculated omitting the term in parenthesis. The quantity of pentane in the B-2H stream is then calculated as previously discussed and illustrated at the bottom of the table. The calculated value of 226 moles/hr. matches the value of 230 based on the original assumption, and the composition of the B-2L stream as given in the last column is established by using the calculated mD value for the pentane concentration.

The calculations are then continued up the column taking material balances around the flash drum and the B-2 and successive stages. It was found that the pentane concentration decreases as the concentrations of the other paraffinic compounds increase, and the composition of the extract on a solvent-free and pentane-free basis will approach a constant or pinch composition. The total quantity of light phase will increase initially in the column and then decrease to the final pinch quantity. Figure 14 shows the variation of the quantities at all the stages below the feed.

As in multicomponent distillation some of the lighter components which in this case correspond to those more soluble in the hydrocarbon phase, increase at the expense of the other light components, and it can be seen that the C_{6P} has reached its maximum concentration while the C_{7P} is approaching its maximum, and the C_{9P} and C_{10P} quantities are still far from their maxima. Similarly all the aromatics have passed their maxima and are approaching constant quantities. Thus, there is little to be gained by increasing the stages below the

feed beyond 7 or 8 theoretical stages at the given operating conditions of reflux and solvent ratios.

The stagewise calculations are matched by starting at the top of the column and approaching a matching composition. In starting the calculations from the top of the column, it is first necessary to determine the amount of solvent which will dissolve in the raffinate to saturate it and simultaneously determine the composition of the solvent phase, which will be in equilibrium with the raffinate. This is analogous to the dew point calculation on the top tray vapor of a distilling column, although the actual calculation technique is more closely related to the dew point calculation on the tail gas of an absorber. In the latter case, the solvent corresponds to the lean oil.

Before proceeding with this calculation, the basis for selecting the apparently arbitrary concentration of pentane in the raffinate will be discussed. This was established from a consideration of the raffinate stripper design. This column operates at a reflux ratio of 2 and the feed by flashing down from 300° F and 200 psig to 260° F and 5 psig supplies two thirds of the reboiler duty. The reboiler duty is the minimum required to strip the bottoms free of pentane. A larger quantity of pentane in the feed will require a greater amount of reboiler vapor. On the other hand, a lower pentane concentration will require the same amount of reboiler duty to maintain the minimum vapor to bottoms ratio for complete stripping of the pentane from the bottoms. The pentane quantity selected for the raffinate composition therefore represents the maximum amount of pentane that can be stripped from the raffinate at the minimum reboil ratio.

It can be seen from the stagewise variation of pentane below the feed that only a fraction of a stage will be required to reduce the pentane concentration of the raffinate appreciably, and it is also possible to design the extractor to substantially eliminate the pentane in the raffinate. In this case, it would probably be necessary to partially cool the raffinate before extracting it with

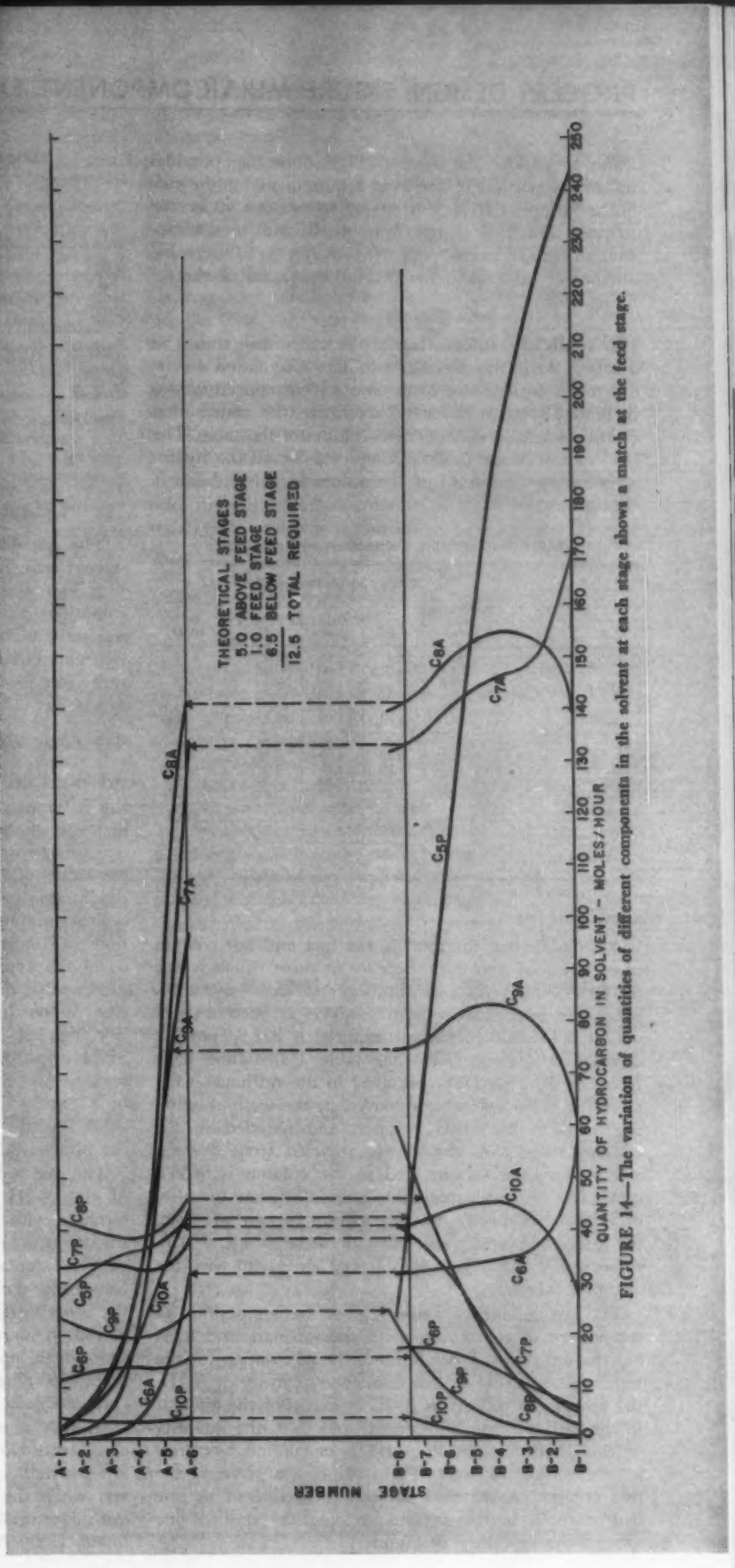

FIGURE 14—The variation of quantities of different components in the solvent at each stage shows a match at the feed stage.

water to remove the solvent. This subcooling provides the major portion of the heat requirements of the raffinate stripper. It is convenient to remove it in the stripper which is a relatively small and inexpensive column which simultaneously provides a considerable amount of latitude in the over-all operation of the refining unit.

The solubility calculation of the raffinite is shown in Table 7. As in the previous solubility calculation on the extract, it is necessary to assume solvent concentrations in both phases in order to determine the distribution coefficients given in the fourth column of the table. The last column of the table is completed for all the hydrocarbons, and the total of the values in this column is obtained.

TABLE 7—Solubility Calculation on Raffinate

	Solubility Calculation on Raffinate				
	Raffinate A-1L m/hr	$\gamma_{.973}$	$\gamma_{.027}$	D	m/D
C_{5P}	29.0	26.4	1.03	25.9	1.12
C_{6P}	14.4	31.5	1.03	30.9	.47
C_{7P}	49.2	38	1.03	37.3	1.32
C_{8P}	74.4	44.5	1.03	43.6	1.70
C_{9P}	49.9	54	1.03	53.0	.94
C_{10P}	10.0	64	1.03	62.8	.16
C_{6A}	.....	5.3	1.29	4.05	.....
C_{7A}	.1	6.45	1.29	4.92	.020
C_{8A}	.4	7.95	1.29	6.07	.066
C_{9A}	.7	9.5	1.29	7.26	.096
C_{10A}	.8	11.4	1.29	8.7	.092
Total Hcbns	228.9	.....	.....	.....	5.984
DEG	6.1	1.00	39	.0266	229
Total	235.0	.....	.....	.....	234.984

$$\frac{228.9-5.98}{1-.0266} = 229.$$

At equilibrium, the total in the first and last column must be equal, and the difference in these values is due to the solvent. With a distribution coefficient of 0.0266, every unit in the last column produces an increment of 0.9734. The total increment required is 222.9, and the calculation is given below the table. Calculating back from the 229, the DEG dissolved in the raffinate is 6.1 moles/hr. This solvent is removed in the wash column, recovered in the DEG stripper, and recycled to the column along with the solvent recycled from this extract. Thus, the solvent feed to the column is 5656.1 moles/hr. of which only the original design quantity of 5650 passes downward. The solvent concentrations in the heavy and light phase calculate to be .974 and .026, respectively, which is in satisfactory agreement with the assumed values.

The last column of Table 7 gives the composition of the solvent in equilibrium with the raffinate and leaving the top stage. **Table 8** shows the calculation for the top stage. In order to determine the quantity of A-1H, the amount of solvent in A-2L in excess of the amount in the raffinate can be ignored, and thus, the quantity of each hydrocarbon in A-1H is calculated based on a total solvent of 5650. These values are given in the first column. A material balance is considered on the hydrocarbons in the streams crossing the dashed line around the top stage in Figure 13.

TABLE 8—Stage Calculation for the Top Stage

	Stage Calculation for the Top Stage					
	A-1H m/hr	A-2L m/hr	$\gamma_{.973}$	$\gamma'_{.030}$	D	m/D
C_{5P}	27.6	56.6	26.4	1.03	25.5	2.12
C_{6P}	11.6	26.0	31.5	1.03	30.6	.85
C_{7P}	32.6	81.8	38	1.03	36.9	2.22
C_{8P}	42.0	116.4	44.5	1.03	43.2	2.70
C_{9P}	23.2	73.1	54	1.03	52.5	1.39
C_{10P}	4.0	14.0	63	1.03	61.1	.23
C_{6A}	.....	.....	5.3	1.29	4.11	.....
C_{7A}	.5	0.6	6.45	1.29	5.00	.12
C_{8A}	1.6	2.0	7.95	1.29	6.16	.325
C_{9A}	2.4	3.1	9.5	1.29	7.37	.42
C_{10A}	2.3	3.1	11.4	1.29	8.84	.35
Total Hcbns	147.8	376.7	.....	.....	.....	10.725
DEG	5655.3	11.4	1.00	33	.0303	377.4
Total	5803.1	388.1	.....	.....	.....	388.1

$$\frac{376.7-10.7}{1-.0303} = 377.$$

The calculation again requires an assumption of the solvent concentration in both phases, but similar to the technique applied to the stages below the feed, the assumptions can be checked out by first considering only the activity coefficients of the solvent. The activity coefficients out of the solvent phase will be substantially unity, and for a first trial, the Σ mD for the hydrocarbons in the last column can be pro-rated from the values in Table 7 as $5.98 \times \frac{376.7}{228.9}$ or 9.8. Thus, the difference between the first and last columns is almost 367, and trying different values of the activity coefficient of the solvent out of the hydrocarbon at different concentrations according to the technique described in Table 7 gave the values of solvent concentrations used to evaluate the distribution coefficients in Table 8.

Determining the Σ m/D for the hydrocarbons and then calculating the value for the solvent necessary to check the solubility calculations as shown at the bottom of the table gives a value of 377 by slide rule calculation. When the quantity of solvent in the A-2L stream is calculated, it is apparent that the value needed is 377.4 as shown. The quantity of solvent in A-2L is greater than the quantity in the raffinate by an amount of 5.3 moles. This will increase the quantity of solvent in A-1H to 5655.3, but this will not change any of the previously calculated hydrocarbon quantities.

The last column of the table gives the composition of the A-2H stream, and since the quantity of internal recycle solvent will increase down the column, the quantities of each of the hydrocarbons in this stream can be calculated based on 5660 moles/hr. of solvent. Repeating these stage calculations down the column, the concentrations of the aromatic hydrocarbons are observed to increase very rapidly between the fifth and sixth stage, and Figure 14 shows the variation of the quantities above the feed and the final matching of components at the feed stage.

In this matching it must be recognized that the amounts of the aromatics in the section above the feed are essentially proportional to the quantity in the raffinate, while the amounts in the section below the feed are substantially independent of the amount in the raffinate. Conversely, the amounts of the paraffins below

the feed are essentially proportional to the quantity in the extract, while the amounts above the feed are independent of the latter values. The quantities match fairly well at A-6 and between B-7 and B-8, and if the match is selected on the basis of the pentane, it occurs at B-7.5. At this stage most of the components match within 10% and two larger discrepancies of about 20% occur with C_{9A} and C_{6P}. Based on the previous relationship a perfect match can be obtained by reducing the C_{9A} in the raffinate by 0.15 moles/hr. and adjusting all other quantities by smaller amounts.

It should be noted that the C_{10P} was carried in the calculations from the top of the column and had been omitted in the calculations below the feed stage. When the feed stage was selected the quantities of C_{10P} below the feed were calculated and the curve is given in Figure 14. The amount in the extract product was less than 0.01 moles/hr. and the quantities on all the other stages did not affect the total hydrocarbon concentrations appreciably. The C_{6A} was handled similarly being omitted in the initial stagewise calculations above the feed. Completing the calculations indicated about 0.01 mole/hr. in the raffinate product and the effect on the total hydrocarbon concentrations in the stages above the feed was also negligible.

The final adjustment of the material balance in this case gave compensating changes in the hydrocarbon concentrations throughout the column so the initial concentrations pattern was retained and the distribution coefficients at the different stages were unaffected.

It may also be stated that the agreement of the initially assumed separation of aromatics and paraffins with the final calculated distribution was not fortuitous. The product distribution had been estimated from a set of calculations on another feed composition and separation using the relative rejection and retention ratios for the paraffins and aromatics respectively by methods similar to those used in multicomponent distillation calculations.

A perfectly matched set of calculations can be developed by the Thiele and Geddes[18] method as demonstrated on liquid extraction calculations by Karr and Scheibel.[7] Table 9 shows the matching of the C_{9A} and C_{8P} components in the present design. The total quantities and the distribution coefficients are taken from the stagewise calculations. The calculations shown below the final values in the quantity columns are based on unit quantities in the end products. The quantities in the B-7.5 stage are interpolated, and the over-all retention ratio of the C_{9A} is thus calculated as 138/1.528 or 90.5, and thus the amount in the raffinate is 50/91.5 or .55 mole/hr. Using this over-all distribution in the column, the quantities in each stage are calculated.

It should be noted that the separation obtained in the flash drum must be included to give the proper over-all separation, and the vaporization constant is evaluated as the γ P value from Table 5 divided by the total pressure of the flash drum. This vaporization constant is utilized exactly the same as the distribution coefficient in the extraction calculations.

The Thiele and Geddes calculations for the C_{8P} are also shown in Table 9, and the rejection ratio of this component is 98/.627 or 156, so the amount in the extract product is 75/157 or 0.48 mole/hr. The actual quantities calculated for each stage are shown in the last two columns. These calculations can be made for all components, and the total quantities and compositions of both phases can be calculated for all the stages. The total quantities must check the values used in the preliminary calculations, and the compositions must give the same distribution coefficients as originally used. The method has the advantage that the deviations can then be corrected at the particular stage and the calculations

TABLE 9—Matching of Components by Thiele and Geddes Method for 12½ Stage Column

	TOTAL QUANTITIES		COMPONENT C_{9A}				COMPONENT C_{8P}			
					QUANTITIES				QUANTITIES	
STAGE NO.	Light Phase m/hr	Heavy Phase m/hr	D	LD / H	In L m/hr	In H m/hr	D	LD / H	In L m/hr	In H m/hr
A-1	235	5803	7.26	.293	.55 1.0	1.87 3.41	43.6	1.77	74.52 1.0	42.1 .565
A-2	388	5817	7.37	.491	2.42 4.41	4.91 8.98	43.2	2.88	116.62 1.565	40.5 .543
A-3	402	5847	7.14	.491	5.46 9.98	11.1 20.3	41.6	2.86	115.02 1.543	40.4 .541
A-4	432	5898	6.75	.494	11.65 21.3	22.45 41.1	39.6	2.90	114.92 1.541	39.7 .533
A-5	483	6090	6.05	.480	23.0 42.1	47.90 87.8	35.0	2.78	114.22 1.533	41.1 .552
A-6	675	6273	5.95	.643	48.45 88.8	75.55 138.	23.0	2.48	115.62 1.552	46.7 .627
B-8	...	6262	6.10	....	.....	74.65 1.510	23.6	....	.....	.....
B-7.5	...	6273	....	....	.....	75.55 1.528	....	....	.....	112. 46.7 98.
B-7	340	6283	6.10	.330	25.2 .510	78.45 1.545	24.0	1.30	46.22 111.	40.68 85.4
B-6	361	6334	5.87	.335	29.0 .545	80.35 1.625	23.2	1.32	40.2 84.4	30.48 63.9
B-5	412	6361	5.82	.377	30.9 .625	82.05 1.659	28.0	1.81	30.0 62.9	16.58 34.7
B-4	439	6394	5.68	.390	32.6 .659	83.35 1.686	22.2	1.52	16.1 33.7	10.58 22.2
B-3	472	6395	5.66	.418	33.9 .686	81.15 1.641	21.6	1.59	10.1 21.2	6.54 13.3
B-2	473	6402	5.64	.416	31.7 .641	76.15 1.540	21.8	1.61	5.86 12.3	3.64 7.64
B-1	480	6371	5.64	.425	26.7 .540	62.85 1.271	21.8	1.64	3.16 6.64	1.93 4.04
Flash Drum	407	5964	3.97*	.271	13.4 .271	49.45 1.0	44.5*	3.04	1.45 3.04	.48 1.0

* Vaporization Constants.

revised without necessitating a completely new set of stagewise calculations. Thus, when the quantity and composition pattern has been established by a preliminary set of stagewise calculations, the final trimming of the quantities can be made most conveniently by the Thiele and Geddes method.

Table 10 shows the final adjustment of the over-all material balance for an extraction column of 12½ theoretical stages with 5 above the feed stage and 6½ below the feed stage. The separation obtained gives .89% aromatics in the raffinate on a pentane-free basis and 0.65% paraffins in the extract on a pentane-free basis. This is slightly better than the original specifications which can probably be obtained in a column containing 12¼ theoretical stages.

TABLE 10—Final Adjustment of Material Balance for 12.5 Theoretical Stages

	Feed m/hr	Final Raffinate m/hr	Final Extract m/hr
C_{6P}	15	1.0	14.0
C_{8P}	15	14.47	.53
C_{7P}	50	49.21	.79
C_{8P}	75	74.52	.48
C_{9P}	50	49.86	.14
C_{10P}	10	9.99	.01
Total Paraffins	200	198.05	1.95
C_{6A}	25	.01	24.99
C_{7A}	100	.10	99.90
C_{8A}	100	.40	99.60
C_{9A}	50	.55	49.45
C_{10A}	25	.73	24.27
Total Aromatics	300	1.79	298.21
Total Hydrocarbons	515	200.84 0.89% Arom.	314.16 0.65% Pffns.

What Liquid Extraction Can Do

The flowsheet for separating aromatics and paraffins from a reformate by fractional liquid extraction using diethylene glycol eliminates the extractive distillation column generally associated with extractor in the conventional Udex process. By operating at conditions under which the solvent does not change in temperature throughout the process, the heat requirements are reduced to an absolute minimum. Effecting the complete separation in the extraction column requires a somewhat larger solvent ratio than in the conventional Udex process.

In the present calculations, the design was based on a solvent to feed ratio of 8:1 on a volume basis, however, by employing more stages, this ratio can be reduced somewhat, but is was not possible to achieve the specified separation at a solvent ratio of 6:1. The Udex process employs solvent ratios in the range of 3:1 to 6:1 and thus cannot give the same separation in the extractor. The present process does not propose any change in the balance of the Udex operation, since a water wash of both hydrocarbon products is necessary to recover the solvent, and the water is then stripped from the recovered solvent so it can be recycled to the extractor.

It is interesting to consider the merits of a complete extraction process relative to an extractive distillation process. The correlation in Figure 11 can be extrapolated to indicate that, aromatic compounds containing over nine more carbon atoms than the paraffinic compounds, cannot be separated by liquid extraction. Thus, this process requires that the hydrocarbon fraction cover a range of less than nine carbon numbers for a complete separation in the extractor.

Using the same activity coefficient curves, the vaporization constants required for a separation by extractive distillation can be calculated as demonstrated in Table 5. It will be seen that paraffins containing four carbon atoms more than the aromatics have the same constants and cannot be separated. Thus, an extractive distillation process requires a hydrocarbon fraction covering not more than three carbon numbers for a complete separation of aromatics and paraffins.

The liquid extraction process can thus be applied to very wide fractions, about three times those necessary for an extractive distillation. In addition, the flash separation in the present process preferentially removes the low carbon number paraffinic compounds from the aromatic fraction. These are the most difficult to separate in the extractor. While the flash will not permit the use of hydrocarbon fractions covering 12 carbon numbers as is theoretically possible using an extractive distillation operation in conjunction with the extractor, it may be utilized to extend the application of the extractor fractions covering more than nine carbon numbers, and there is no doubt that it does facilitate the complete separation of narrower fractions and reduce the number of stages required. The basic function of the separation is to provide the necessary reflux to achieve a complete separation in the extractor. The added advantage of preferentially refluxing the compounds difficult to separate in the extractor makes it preferable to removing all the aromatics from the extract stream and refluxing a fraction of the total stream which is the usual procedure in this type of process.

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Proven Pressure Vessel Design Methods

In designing high pressure-temperature vessels, try this method of analyzing the strength and ductility in creep and stress-rupture tension tests

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SITUATIONS FREQUENTLY arise which call for the design of tubular vessels to operate at temperatures above 100 F. In many cases the temperature is below the creep range (about 500-700 F. for steel), in which case it is usually sufficient to design on the basis of properties of the materials at temperature. At higher temperatures it is necessary to design on the basis of both creep and stress-rupture, with due allowance for safety factors. A complete formulation of design procedure is beyond the scope of this article; the main purpose here is to show how one might go about calculating creep and stress-rupture limits for statically operated vessels under uniform temperature conditions. Design considerations of fatigue,[4,9] stress concentration,[3] and corrosion,[6,7] may be found in the literature cited.

The author has operated several tubes designed according to the procedure outlined and has not yet experienced a tube failure. In the discussion to follow, the specific case of a closed-end cylinder of Type 347 stainless steel will be considered.

Design Below Creep Range—Elastic-Range Design. Suppose that a closed-end tube of Type 347 stainless steel is to operate at about 500 F. and 10,000 psi internal pressure. Process requirements call for a vessel having an internal diameter of 6 inches, which should not expand (at temperature) more than ½ percent under the applied pressure. It is also specified that the factor of safety on yielding be 1.5 and that the factor of safety on bursting be 4.0.

Since the operating pressure is 10,000 psi, and the factor of safety on yielding is 1.5, the design yield pressure will be 15,000 psi; a factor of safety of 4 on bursting requires a design bursting pressure of 40,000 psi. The solution to this aspect of the problem is relatively simple by noting that

σ_y (0.01% offset) = 30,000 psi at 500 F.
σ_y' (0.20% offset) = 35,000 psi at 500 F.
σ_u = 75,000 psi at 500 F.
μ = 0.3 at 500 F. (assumed)
E = 25,250,000 psi at 500 F.

and the following design formulas.[2]

1. $(\sigma_{h\varepsilon})_{max.} = p\left(\frac{R^2+1}{R^2-1}\right)$
2. $(\sigma_r)_{max.} = -p$
3. $(\sigma_{z\varepsilon})_{max.} = \frac{p}{R^2-1}$
4. $p_y = \frac{\sigma_y}{\sqrt{3}}\left(\frac{R^2-1}{R^2}\right)$
5. $p_b = \frac{2\sigma'_y \ln R}{\sqrt{3}}\left(2-\frac{\sigma'_y}{\sigma_u}\right)$
6. $\varepsilon_h = \frac{1}{E}\left[\sigma_{h\varepsilon} - \mu(\sigma_{z\varepsilon})\right]$

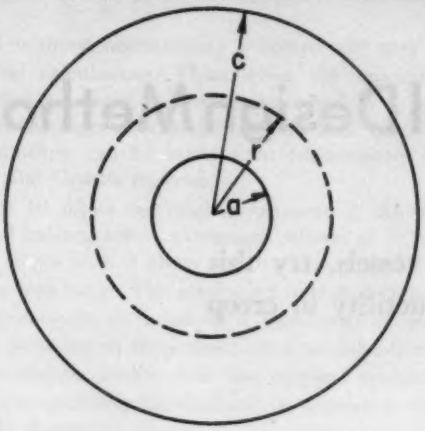
The diameter-ratio to meet the yield requirement (Equation 4) is calculated to be 2.76. From Equation 5 the required diameter ratio is 1.91; and, from Equation 6 it is found that the conditions imposed result in considerably less than ½ percent bore expansion. Therefore, the limiting condition is the yield pressure, and the value of 2.76 calculated from Equation 4 is selected as the proper diameter ratio for the vessel; the O.D. is thus 16.56 inches.

Provision is made as follows in the ASME Code[7] for calculating the wall thickness of tubes operating under an internal pressure of 3,000 psi, or less, when the thickness exceeds a/2 or when $p > 0.385\,SK$,

7. $t = a\left[\sqrt{\frac{SK+p}{SK-p}} - 1\right]$

The above formula, while mandatory only for pressures of 3,000 psi or less, is frequently used for higher pressures since, in the absence of a specified formula, it represents the only official published method for design. Since the problem here involves a monobloc with no longitudinal seams, the efficiency factor K becomes 100 percent and Equation 7 reduces to

8. $p = S\left[\frac{R^2-1}{R^2+1}\right]$



$$R_1 = \frac{r}{a} \qquad R = \frac{c}{a}$$

FIGURE 1—Geometry of cylinder.

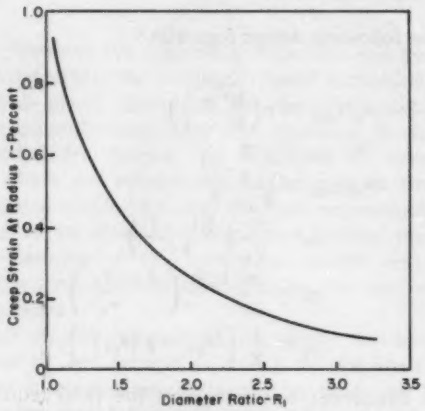


FIGURE 2—Distribution of creep strain through tube wall.

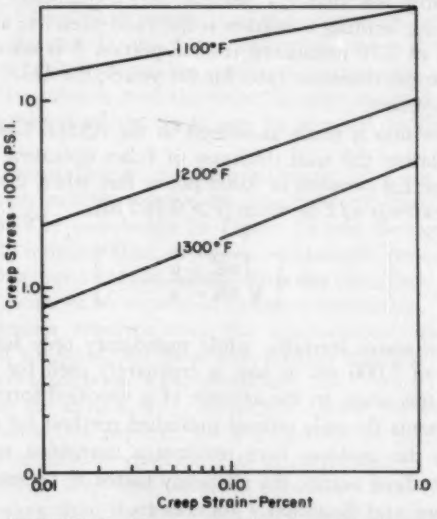


FIGURE 3—Creep stress-creep strain curves for Type 347 stainless steel at various temperatures for 1,000-hour operation.

The code specifies an allowable stress of 18,000 psi for the material at 500 F.; therefore, if the design pressure is taken as 15,000 psi, the required diameter ratio from Equation 8 would be 3.34. If the allowable pressure is taken as 40,000 psi, Equation 8 indicates that not even a tube with infinite diameter ratio would suffice; therefore, in this particular case, the code formula indicates that for the vessel to operate at 10,000 psi, with a factor of safety of 4, no solution exists. For the factor of safety of 1.5, the required diameter ratio of 3.34 is 21 percent greater than that required by Equation 4; that this excess of material is unnecessary (in the absence of corrosion) is shown by the fact that Equations 4 and 5 provide for a factor of safety of 6.5 on bursting, and the formulas have been demonstrated to be reliable to better than ±15 percent on a 90 percent certainty basis.[2]

If, for the same material, the working pressure is 1,000 psi, and the same factors of safety of 1.5 on yielding and 4 on bursting are used, then Equations 4 and 5 result in a specified diameter ratio of about 1.10; the code specifies essentially the same dimensions. It is thus seen that the greatest divergences occur for the higher operating pressures and that in the high pressure range it is advisable to use Equations 4 and 5 rather than Equation 8. The former equations have the advantage of giving information on both elastic behavior and bursting, whereas Equation 8 does not specify whether the action is elastic or not.

Inelastic Design. The design method outlined here follows many of the recommendations of Siebel and Schwaigerer[3] for creep analysis but extends design considerations to include stress-rupture as well. As in the previous section of the paper, the closed-end tube of Type 347 stainless steel will be considered, and for the sake of brevity it will be assumed that the design concerns a vessel whose life can be limited to 1,000 hours of operation. The same methods could easily be applied to vessels having a desired useful life of much longer duration.

Creep Behavior. The simplest criterion is that of allowing a certain amount of creep to occur before the vessel is considered unusable; if, for example, the allowable bore creep is 1 percent, then analyses of safe pressures can be made starting with 1 percent bore expansion as a basis. Since it is assumed that the volume remains constant in the plastic range of strain, the following relationship can be written down which relates the bore strain to any other hoop strain in the cylinder wall; thus, referring to Figure 1,

$$9. \qquad \varepsilon_a = \varepsilon_r R_1^2$$

Using Equation 9 and the condition that $\varepsilon_a = 1$ percent, Figure 2 can be prepared.

Now, taking the tube previously designed, having a diameter ratio of 2.76, the safe maximum internal pressure for 1,000 hours of operation at elevated temperature will be calculated; creep data for 1,000-hour operation at various temperatures are given in Figure 3 for uniaxial loading. With Figures 2 and 3 available, Figure 4 is obtained by superposition; this latter figure shows, for diameter ratios R_1, the equivalent uniaxial creep stress. For example, for 1200 F., 0.10 percent creep strain represents a stress of about 5,000 psi (Figure 3); from

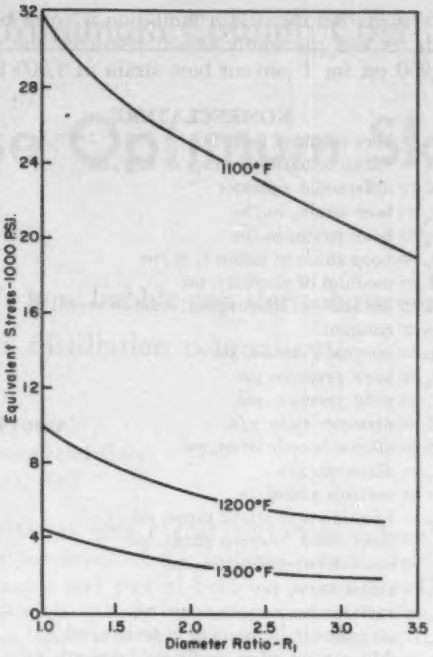


FIGURE 4—Distribution of equivalent stress through wall for 1,000-hour operation.

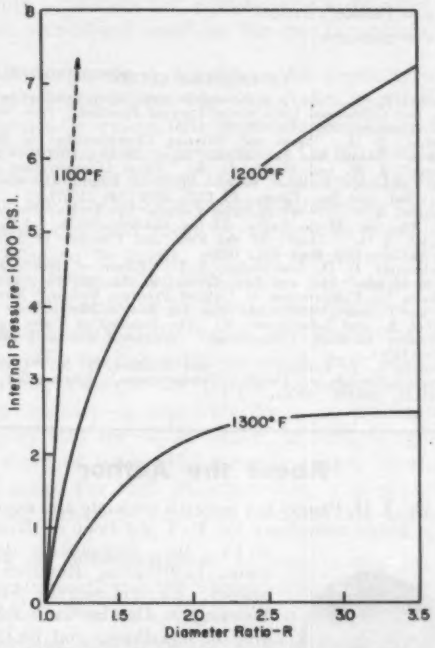


FIGURE 5—Permissible internal pressure for tubes of Type 347 stainless steel to operate for 1,000 hours at maximum of 1 percent bore creep strain.

Figure 2 a strain of 0.10 percent corresponds to a diameter ratio R_1 of 3.25; thus, on Figure 4, for 1200 F., a point is plotted at 5,000 psi and $R_1 = 3.25$. The ordinate is called "equivalent stress" since it represents, through theory[2,5] the effect of combined loading in terms of uniaxial stress values; thus,

10. $$\sigma_e^2 = \sigma_h^2 + \sigma_r^2 + \sigma_z^2 - \sigma_h\sigma_r - \sigma_r\sigma_z - \sigma_z\sigma_h$$

Figure 4 furnishes the basic information from which to determine permissible internal pressures for the tube in question.

For equilibrium in a tube it is required that[5]

11. $$p = \int_a^c (\sigma_h - \sigma_r)\frac{d\sigma_r}{r}$$

in which it is assumed that[5]

12. $$(\sigma_h - \sigma_r) = \frac{2\sigma_o}{\sqrt{3}}$$

Using Equations 11 and 12 and integrating for various diameter ratios R_1, the stress values as given by Figure 4 are used to obtain the curves plotted in Figure 5, which show the permissible internal pressures for tubes to operate at a maximum of 1 percent bore strain for 1,000 hours. For example, for a diameter ratio of 2.76 Figure 5 shows that the maximum permissible internal pressure at 1200 F. is 6,250 psi.

Stress-Rupture Behavior. Many cases of failure are known where tubes have spontaneously cracked with little or no evident ductility. Thus, the possibility of stress-rupture must be carefully considered in design since it could well be the limiting condition. Unlike the creep analysis, above, it is necessary here to obtain specific stress values and to relate these, through theory, to a limiting pressure. An approximate statement of the stress distribution through the tube wall has been given by Bailey[1] as follows:

13. $$\sigma_{hc} = p\,\frac{\left[\left(\frac{1}{R}\right)^{\frac{2(x+1)}{n}} - \left\{1 - \frac{2(x+1)}{n}\right\}\left(\frac{a}{r}\right)^{\frac{2(x+1)}{n}}\right]}{1 - \left(\frac{1}{R}\right)^{\frac{2(x+1)}{n}}}$$

14. $$\sigma_{rc} = p\,\frac{\left[\left(\frac{1}{R}\right)^{\frac{2(x+1)}{n}} - \left(\frac{a}{r}\right)^{\frac{2(x+1)}{n}}\right]}{1 - \left(\frac{1}{R}\right)^{\frac{2(x+1)}{n}}}$$

15. $$\sigma_{zc} = p\,\frac{\left[\left(\frac{1}{R}\right)^{\frac{2(x+1)}{n}} - \left\{1 - \frac{x+1}{n}\right\}\left(\frac{a}{r}\right)^{\frac{2(x+1)}{n}}\right]}{1 - \left(\frac{1}{R}\right)^{\frac{2(x+1)}{n}}}$$

where x and n are constants having the following values

Creep Behavior	x	n	$\frac{x+1}{n}$
Elastic	p	p + 1	1.000
Primary	2	4	0.750
Secondary	0	4	0.250
Tertiary	—0.5	4	0.125

Bailey points out, in his equations, above, that when $n = (x + 1)$, the type of stress distribution obtained is

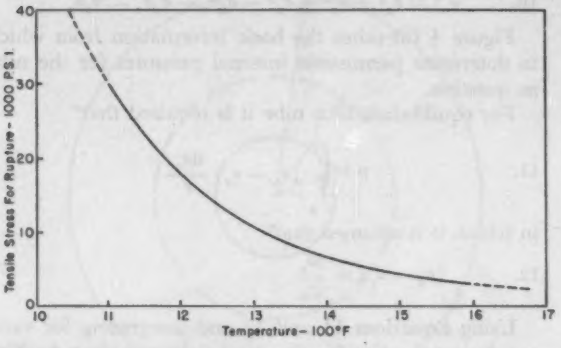


FIGURE 6—One thousand-hour stress rupture data for Type 347 stainless steel.

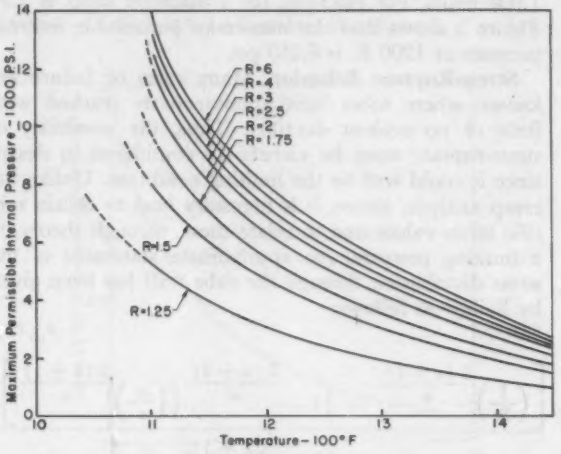


FIGURE 7—Maximum permissible internal pressure for 1,000-hour rupture life for tubes of Type 347 stainless steel.

the same as that obtained in elastic loading. He further points out that the factor $\frac{x+1}{n}$ equals approximately 1.0 for austenitic stainless steel so that, calculating the maximum stresses from Equations 13-15, for r = a, and substituting into Equation 10, the result is

16. $$\sigma_o = p\left[\frac{\frac{2\,(x+1)}{n}}{1-\left(\frac{1}{R}\right)^{\frac{2\,(x+1)}{n}}}\right]$$

or, for austenitic stainless

17. $$\sigma_o = 2p\left(\frac{R^2}{R^2-1}\right)$$

Equation 17 can now be used to calculate safe pressures for Type 347 stainless steel for 1,000-hour operation at various temperatures. The results of such computations are shown on Figure 7, where the ordinate has been calculated using Equation 17 based on σ_0 values from Figure 6. From Figure 7 it is seen that, for a tube of diameter ratio 2.76 at 1200 F., the maximum permissible pressure is about 7,400 psi. Therefore, for 1,000 hours' operation the design limitation is creep behavior, which, as was previously noted, restricted the pressure to 6,250 psi for 1 percent bore strain at 1,000 hours.

NOMENCLATURE

- a = bore radius of tube, in.
- c = radius to outside surface of tube, in.
- d = differential operator
- ϵ_a = bore strain, in./in.
- ϵ_h = hoop strain, in./in.
- e_r = hoop strain at radius r, in./in.
- E = modulus of elasticity, psi
- K = efficiency of longitudinal seam in vessel, %
- n = constant
- p = internal pressure, psi
- P_b = burst pressure, psi
- P_y = yield pressure, psi
- R = diameter ratio, c/a
- S = allowable code stress, psi
- R_1 = diameter, r/a
- r = variable radius, in.
- σ_{hr} = hoop stress in elastic range, psi
- σ_{hc} = hoop stress in creep range, psi
- σ_o = equivalent tensile stress, psi
- σ_r = radial stress, psi
- σ_{rc} = radial stress in creep range, psi
- σ_u = ultimate tensile strength in tension, psi
- σ_y = 0.01 percent offset tensile yield strength, psi
- σ'_y = 0.20 percent offset tensile yield strength, psi
- σ_{zs} = longitudinal stress in elastic range, psi
- σ_{zc} = longitudinal stress in creep range, psi
- t = wall thickness, in.
- μ = Poisson's ratio
- x = constant

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For Minimum Column Cost . . .

Use Optimum Slot Submergence

Here's how bubble cap slot submergence affects distillation column cost

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The Chemstrand Corp.
Pensacola, Fla.

MINIMUM COST CRITERIAS have been developed for many of the variables which affect the performance and cost of bubble tray columns. However, no such analysis has been made concerning the depth of liquid seal. For the usual distillations, it has been customary to employ seal depths in the range of 1 to 2 inches. The minimum cost bubble tray column should have a design slot submergence or seal depth of approximately 3.5 inches. Any tray design employing a different slot submergence is probably not the most economical vessel for the specific application.

Slot submergence is defined as the depth of clear liquid above the bubble cap vapor slots. As the slot submergence is raised, the tray efficiency increases, although not in direct proportion. To insure a high tray efficiency, the time of contact between the liquid phase on the tray and the vapor phase passing through the bubble cap slots must be as long as possible to allow diffusion to occur, and the interfacial surface area between phases must also be as large as possible.

This is accomplished by having deep pools of liquid on each tray so that the vapor bubbles leaving each cap slot will have a relatively long path to travel while rising through the liquid. In addition, when the gas velocity is relatively high, it is dispersed thoroughly into the liquid which, in turn, is agitated into a froth or foam. This provides large, interfacial surface areas. For high efficiency then, a deep pool of liquid and relatively high gas velocities are required.

Criteria of Submergence. In some cases, process considerations dictate the choice of slot submergence. High liquid rates are encountered in many absorption and stripping operations particularly in large towers and a high slot submergence is sometimes employed to reduce hydraulic gradient and its resultant vapor maldistribution. Submergence of 12 inches or more is often used when the distillation column is employed as a reactor which requires a long hold-up time of the liquid.

Conversely, when the process requires a vacuum distillation, shallow liquid seals are employed to reduce pressure drop and operating temperatures. The use of lower seal depth also results in the minimum liquid hold-up which is desirable for materials that decompose or polymerize readily.

Effect of Submergence. Slot submergence, through its effect on tray efficiency, is thus one of the factors determining the number of actual trays required in a tower. The allowable vapor velocity decreases as the seal depth is raised for any fixed tray spacing. Slot submergence also influences the tower diameter, as well as the number of actual trays, through its effect on allowable vapor velocity.

It follows, therefore, that since slot submergence exerts some control over the physical dimensions of the tower, when no specific process considerations control this depth, the choice should be made on the basis of its effect on tower costs.

Tray Spacing and Entrainment. The choice of tray spacing and quantity of entrainment is closely related to slot submergence since they also exert some influence on the total cost of the tower. As the slot submergence is increased, entrainment level also increases for a constant tray spacing and tower diameter. The entrainment level used here is defined as the pounds of liquid entrained per pound of dry vapor flow within the tower. In addition to slot submergence then, there is also an economical level of entrainment. This has been determined by Zenz[3] to be 0.175. A schematic illustration of his correlation of entrainment at minimum cost at a fixed throughput, is shown in Figure 1.

Tray Efficiency. Walter and Sherwood[2] equation relating the effect of slot submergence to tray efficiency is given as:

$$E_G = 1 - e^{-m} \qquad (1)$$

$$m = \frac{(S)^{0.8}}{\left(2.5 + \dfrac{0.00594\,\alpha\,M_L}{L/V}\right)\mu_L^{0.68}\,b^{0.33}} \qquad (2)$$

Where S = vertical distance between center of bubble cap slot to top of liquid on tray, inches.
α = relative volatility
M_L = molecular weight of liquid
L/V = internal reflux ratio
μ_L = liquid viscosity, centipoise
b = width of bubble cap slot, inches
E_G = Murphree gas efficiency
e = base (e)

The two terms within the parentheses represent the relative resistance of the vapor and liquid phase, respectively. The slot width influences bubble size and together with S, therefore, the interfacial surface area,

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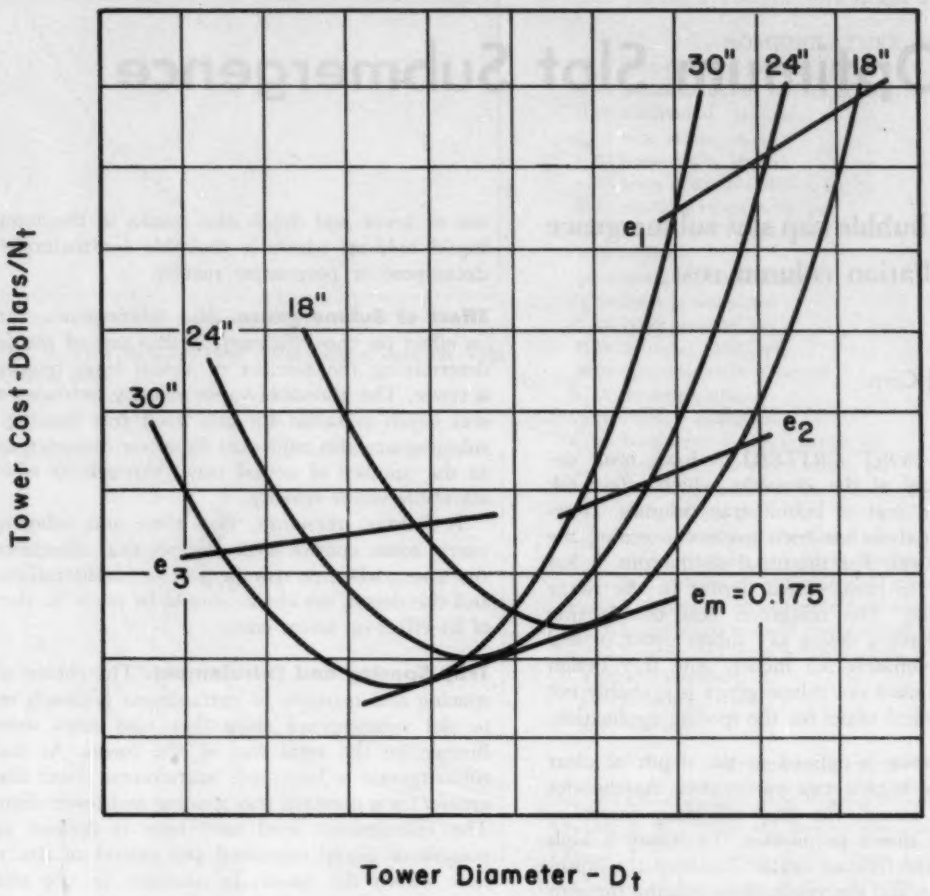
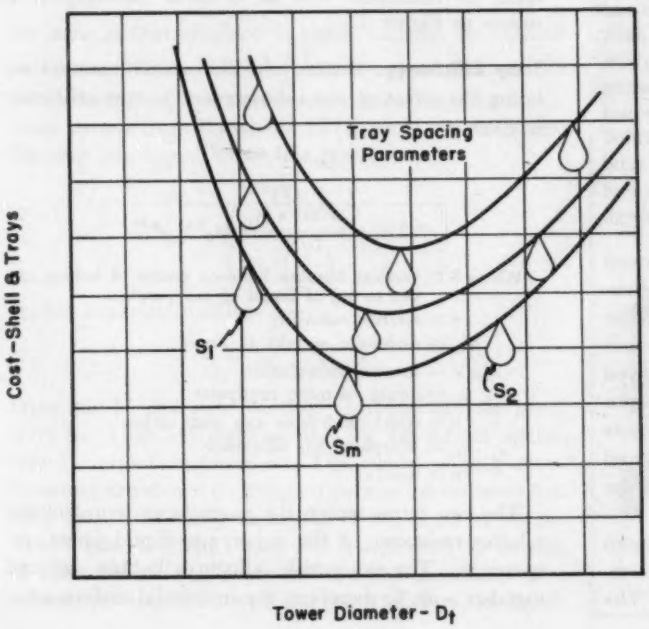


FIGURE 1—Schematic illustrations of optimum entrainment at minimum cost.[3]



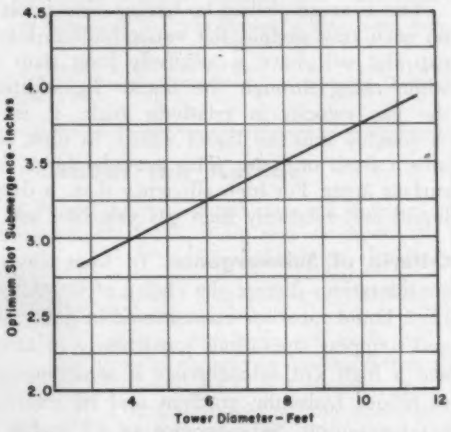


FIGURE 2—(left) Shows the type of correlation from equations (6) and (8) of optimum slot submergence at minimum cost.

FIGURE 3—(above) For minimum cost at various tower diameters the optimum slot submergence varies between 3 and 4 inches.

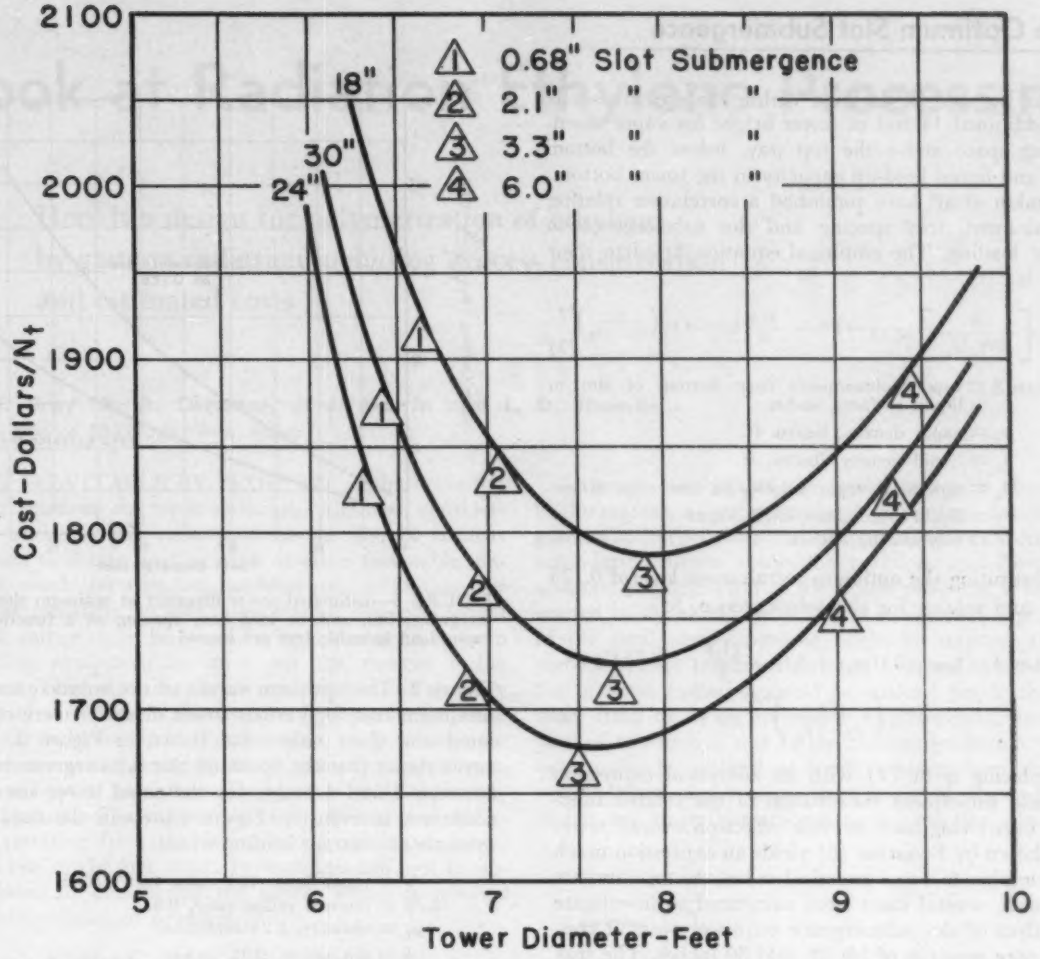


FIGURE 4—Typical solution of equation (6) and (8) at fixed throughput and constant entrainment level. eM of 0.175.

while the term involving μ_L, accounts for the major effect of liquid viscosity on the low diffusion rates within liquids. The definition of α as a function of dy/dx covers variations in tray efficiencies for gas solubilities which do not follow Henry's law.

Colburn's[1] equation relating the effect of liquid entrainment to tray efficiency is:

$$E_a = \frac{E_G}{1 + \frac{e\,E_G}{L/V}} \qquad (3)$$

Where E_a = tray efficiency at entrainment rate, e
e = entrainment rate, lbs. liquid per lb. vapor
L = liquid downflow rate, lbs/hr.
V = vapor up-flow rate, lbs/hr.
E_G = tray efficiency at negligible entrainment

The entrainment level, e, will be set at 0.175 and substituting this value in Equation (3):

$$E_a = \frac{E_G}{1 + \frac{0.175\,E_G}{L/V}} \qquad (4)$$

Substituting the expression for E_G in Equation (1) back into Equation (4):

$$E_a = \frac{1 - e^{-m}}{1 + \frac{0.175 - 0175e^{-m}}{L/V}} \qquad (5)$$

COLUMN COSTS

As a first approximation the major portion of distillation tower costs are accounted for by the shell cost plus tray cost. This simplification neglects the cost of all apertures, foundations, and erection, etc., but expressed the major cost sufficiently for a general comparison of alternate designs. This is the same approach used by Zenz[2] in arriving at his optimum entrainment level criteria for distillation colums. Tray costs are then expressed in terms of dollars per square foot of tray area, and shell cost in terms of dollars per pound. Total cost can be written as:

$$\text{Cost } \$ = (\$/\text{ft.}^2)\frac{\pi D_T^2}{4}\left(\frac{N_T}{E_a}\right) + (\$/\text{lb.})\left(\frac{\pi D_T t T \rho_S}{12} + 14\right) \qquad (6)$$

Where D_T = tower diameter, feet
T = tray spacing, inches
N_T = number of theoretical trays required
ρ_S = metal density, lbs./cu. ft.
t = shell thickness, feet

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The number 14 enclosed within the parentheses is an additional 14 feet of tower height for vapor disengaging space above the top tray, below the bottom tray and liquid hold-up capacity in the tower bottom.

Simkin et al[2] have published a correlation relating entrainment, tray spacing and slot submergence to tower loading. The empirical equation fitted to their data is:

$$e = \left[\frac{S}{60\rho_g U_o}\right] \times 10^{-3.95 + \frac{27.3}{T} + 10.75\, U_o \left(\frac{\rho_g}{\rho_L - \rho_g}\right)^{0.5}} \quad (7)$$

Where S = vapor submergence from bottom of slot to liquid surfaces, inches

ρ_g = vapor density, lbs/cu. ft.

ρ_L = liquid density, lbs/cu. ft.

U_o = superficial vapor velocity in free area, ft/sec.

e = liquid entrainment, lbs/lb. vapor

T = tray spacing, inches

Substituting the optimum entrainment level of 0.175 for e and solving for slot submergence, S:

$$\text{Log } S = \text{Log } (60\, U_o \rho_g) + 3.19 - \frac{27.3}{T} - 10.75\, U_o \left(\frac{\rho_g}{\rho_L - \rho_g}\right)^{0.5} \quad (8)$$

Replacing S in (2) with its analytical expression (8) and subsequent substitution of the related functions in arriving back to their effect on overall tower cost shown by Equation (6) yields an expression much too complex to be of practical value. As an alternate approach, several cases were calculated to investigate the effect of slot submergence on tower costs at constant tray spacings of 18, 24, and 30 inches. The tray free area was conservatively assumed to be 70 percent of the tower cross sectional area, bubble cap slot width of 0.25 inch, tray cost at $15 per square foot and shell cost at 60 to 70 cents per pound depending on tower diameter.

The type of curves resulting from the solution of Equations (6) and (8) are presented schematically in Figure 2. The optimum values of slot submergence at minimum cost for various tower diameter were calculated and these values are shown in Figure 3. This curve shows that the optimum slot submergence varies between 3 and 4 inches for the usual tower sizes encountered in industry. Figure 4 presents the results of one case at constant loading where:

V = vapor load, 183 cubic feet/second

L/V = internal reflux ratio, 0.835

μ_L = viscosity, 0.24 centipoise

b = slot width, 0.25 inches

ρ_g = vapor density, 0.168 lbs/cu. ft.

ρ_L = liquid density, 43.3 lbs/cu. ft.

U_o = allowable vapor velocity in free area, 4.07 ft/sec.

α = relative volatility of key components, 2.4

M_L = molecular weight of liquid, 92

As shown by these curves, the optimum slot submergence is 3.3 inches and the optimum tray spacing for this system is 24 inches.

A generalized curve relating vapor loading to tower diameter at 24 inches tray spacing and at the optimum slot submergence is shown in Figure 5 with entrainment level plotted as a parameter. However, this curve should be used for rapid tower sizing for estimates only since high pressure and vacuum operation tend to shift the curve slightly from that shown.

Qualitative conclusions drawn from this study show that the optimum slot submergence is between 3 and 4 inches for almost all systems encountered in industry. It is felt that this theoretical study will stimulate further interest in this subject and that extensive tests will be initiated to further substantiate these findings.

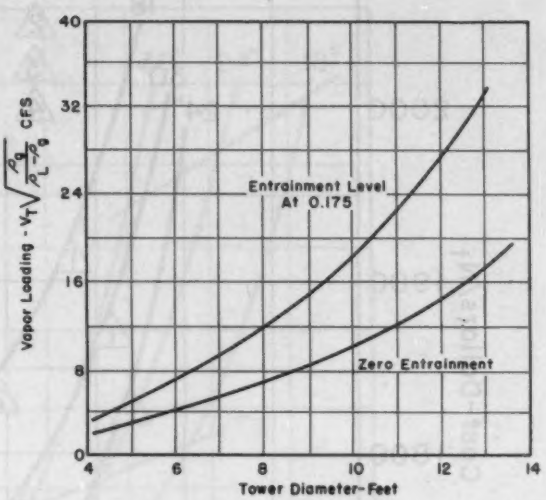

FIGURE 5—Estimated tower diameter at optimum slot submergence, Sm, and 24 inch tray spacing as a function of vapor load in cubic feet per second.

ACKNOWLEDGMENT

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Look at Radiation Ethylene Processing

Here is a design for polymerization of ethylene by gamma radiation including process consideration and estimated costs

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AN INEVITABLE BY-PRODUCT of the operation of any nuclear reactor is radiation. Although considerable attention has been paid to the use of nuclear reactors to obtain heat or work or other fissionable material, much less attention has been paid to finding uses for the radiation. In fact, most reactor designers would much rather there be no radiation to contend with in building equipment to carry out the nuclear fission process. This, of course, is not realistic because the very heart of the fission chain reaction is dependent upon a neutron radiation field. Furthermore, nuclear reactions are always accompanied by the release of some radiation such as beta or gamma as this is one of their characteristic features. The magnitude of the quantity of radiation resulting from the fission reaction is much larger than one might first think. Perhaps this can best be appreciated by considering the energy which is released in the fissioning of uranium-235.

Energy Available. When an atom of uranium is split by the capture of a neutron, approximately 200 Mev (millions of electron volts) of energy will be liberated. However, not all of this will be immediately available, as some of the energy results from certain delayed secondary processes. At the instant of fission approximately 166 Mev, or 83 percent of the total is found in the kinetic energy of the fission fragments. Because these fragments are very large charged particles, they travel only a minute distance before giving up their kinetic energy as heat to the surrounding atoms. About 2½ percent of the total energy of the fission process goes to the kinetic energy of the neutrons. This energy is released as heat largely in the reactor or moderator, though a small amount must be absorbed by the shielding around the reactor. The absorption of neutrons by the various surrounding materials gives rise to a secondary reaction which delivers another 6 percent of the total energy mostly in the form of gamma radiation. Gamma radiation is also given off in the primary fission reaction to the extent of about 2 and ½ percent of the total energy. The remaining 6 percent of the energy is given up by the highly radioactive fission fragments as they undergo secondary nuclear reactions long after the primary fission process. Of this energy from the fission products about 3 and ½ percent is liberated in the form of beta radiation and 2 and ½ percent is gamma radiation.

Although the bulk of the fission energy is absorbed in the reactor, a very appreciable percentage due to the gamma radiation from the primary reaction, from the secondary neutron absorption reaction, and from the ultimate disintegration of the fission products, is simply wasted in the shielding. It is fair to say that 5 percent of the total energy released might be trapped as absorbed gamma radiation and put to some use. Part of this gamma radiation could be utilized inside the reactor itself or in its immediate neighborhood, and the part of it which is due to the radioactive fission products might be utilized at some distance from the reactor. When one realizes that many of the reactors which are being constructed or are on the planning

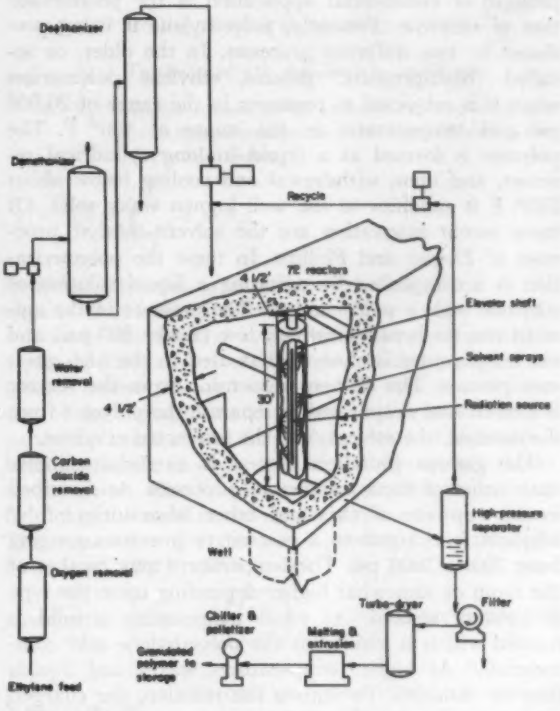

FIGURE 1—Shows a proposed radiopolymerization process for polyethylene with feed purification, reactor and product finishing.

boards are rated in megawatts (millions of watts), it is apparent that 5 percent of this power is going to be quite a substantial amount of gamma radiation. It is not surprising that a number of studies have recently been undertaken to find uses for the gamma radiation directly from nuclear reactors and from fission products. Developments of uses of beta radiation have also received some attention, though its low penetrating power limits its utility in many applications.

Chemical Reactions. Among the promising applications of gamma radiation is the promotion of chemical reactions. The more favorable reactions are those in which a small amount of radiation causes a rather large amount of product to be formed. In such cases one may think of the radiation as supplying a small amount of activation energy which causes a chain reaction to take place. A number of chain reactions that are activated by gamma radiation (and in many cases also by ultraviolet or other forms of electromagnetic or particle radiation) have been discovered.[4] These reactions form the basis of a new field which is called "radiation chemical processing." To date the commercial applications of radiation chemical processing have been more or less limited to ultraviolet processes. However, because of the large supply of gamma radiation which may be available as a result of the nuclear power program, there seems little doubt that gamma processes will soon be taking their rightful place in this field.

Polymerization. One chemical reaction which is promoted by gamma radiation and which shows some promise of commercial application is the polymerization of ethylene. Presently, polyethylene is being produced by two different processes. In the older, or so-called "high-pressure" process, ethylene polymerizes when it is subjected to pressures in the range of 20,000 psi and temperatures in the range of 400° F. The polymer is formed as a liquid in long cylindrical reactors, and upon withdrawal and cooling below about 220° F it solidifies to the well known waxy solid. Of more recent innovation are the solvent-catalyst processes of Ziegler and Phillips. In these the polymerization is accomplished by agitating a liquid solution of ethylene with a solid catalyst. The pressure in the agitated reactor is comparatively low (under 500 psi) and the temperature is close to that used in the high pressure process. The effluent suspension from the reactor is filtered and evaporated to separate the polymer from the catalyst, the solvent, and the unreacted ethylene.

The gamma radiation process is somewhat simpler than either of these commercial processes. As described in the reports of this and other laboratories,[1, 2, 3, 4] ethylene is charged to a reactor to pressures ranging from 200 to 3000 psi. The temperature may be that of the room or somewhat higher depending upon the type of product desired. At room temperature a solid is formed which is similar to the polyethylene sold commercially. At higher temperatures waxes and liquids may be obtained. To initiate the reaction, the charged reactor is simply subjected to gamma radiation. The percentage conversion of ethylene to polymer is dependent upon the strength of the radiation field and the time of exposure. The rate of the reaction is sufficiently rapid to merit this study on the feasibility of a commercial process.

Design and Costs. In the following sections some of the problems are considered for the design of a radiation chemical processing plant to produce polyethylene. A rough estimate has been made to give some comparative figures on the cost of polyethylene produced by the radiation and the conventional processes. The estimate can only be approximate at this time because it is impossible to predict the cost of radiation. It is conceivable that so much by-product radiation will become available that its cost will be negligible. The alternate possibility exists that a demand will develop for radiation and its cost will be comparable to that of other forms of energy. Only time can clarify the answer to this question. Meanwhile, reasonable estimates of radiation costs have been taken to show that the proposed process is competitive with the conventional processes.

DESCRIPTION OF PROPOSED PROCESS

As a basis for the design, 60 million pounds per year of polyethylene was selected as a reasonable production quantity for a medium size plant. The radiation initiation is to be supplied by fission products from a nuclear reactor. The ethylene feed is purified by first removing oxygen, carbon dioxide, and water, and is then passed through two distillation columns. The first tower removes the methane and lighter constituents and the second column removes the ethane and heavier. The ethylene is compressed to 3,000 psia and fed to long cylindrical reactors as a gas. In the presence of gamma radiation the polymer slowly forms in the reactors, only to be washed out by intermittent solvent sprays. The slurried polymer is then separated from the unreacted ethylene, cooled, and filtered to remove the polymer. The polyethylene powder is subsequently dried in a turbodryer, melted, extruded, chilled, and chopped up and sent to storage. The plant is equipped with numerous storage bins, mixers, and blenders in order to achieve a uniform product by blending various batches. On the whole the process is simple and straightforward. All equipment except the reactor and radiation source are of a conventional nature. Figure 1 shows the flow sheet for the radiation process.

Reactor Design. Several types of reactors were considered in this design but only the one which was considered the simplest and most practical is described.

A number of annular cylindrical vessels are to be used as reactors for the ethylene. Each one is 4.5 feet in diameter and 30 feet in length. The diameter of the center hole is 1 foot. The walls of the reactors are constructed of high alloy steel.

The outer wall is 1¾ inches thick while the inner wall is 0.2 inches thick. During the reaction, the radiation source is located in an elevator mechanism in this small, 1 foot diameter, concentric cylinder. The annular reaction volume thereby completely surrounds the source. This arrangement utilizes the available radiation most effectively by intercepting a maximum amount of the radiation. By means of the elevator the source can be raised or lowered from a storage well

into the cylindrical hole in the reactor. The gamma radiation source is a series of short cylinders, which when stacked upon one another, are as long as the reactor itself.

In order to prevent the polymer from clogging the exit of the reactor, high-pressure liquid sprays are used to wash the polymer out of the reactor in a slurry. The sprays also serve to carry away the heat of reaction. It has been shown[2] that no decrease in reaction occurs when water or cyclohexane is present during the polymerization. The slurried polymer can easily be separated from the unreacted ethylene in a high pressure separator.

The design of equipment for this plant is not unusual with the exception of the reactors. Therefore, it is of interest to present only the design of the reactors. In a rigorous calculation these might be designed in incremental stages. However, the accuracy of the data is such that a volume average reaction rate constant may be used to simplify the calculations. This constant is defined as

$$k_{(\text{volume average})} = \frac{1}{V}\int_{O}^{V_R} k\, dV \qquad (1)$$

where

k = Reaction rate constant of a first order reaction (hr^{-1})

V_R = Volume of the reactor

On the basis of the most recent work[2] the reaction rate constant is taken to be proportional to the 0.7 power of the intensity of radiation, or

$$k = K\, I^{0.7} \qquad (2)$$

where

K = Reaction rate constant which is independent of radiation intensity, (hr^{-1}) (kilorep/hr.)$^{0.7}$

I = Radiation intensity (kilorep/hour)

With a source of finite dimensions, such as the cylindrical source considered here, the intensity at any point in the reactor is a function of the position of the point with respect to the source. Because of the symmetry involved in calculation of $k_{(\text{volume average})}$, the actual cylindrical source can be approximated by a finite line source lying on the axis of the cylinder. Rockwell[11] gives relations for the intensity of radiation at any point as a function of the position of the point with respect to the source. In the case of a finite line source, the intensity at any point is given by

$$I = \frac{(I_S r_S)}{r}\left[F(\theta_1, b_1) + F(\theta_2, b_1)\right] \qquad (3)$$

where

$I_S r_S$ = Specific radiation intensity at some reference point S. such as $\left(\frac{\text{rep}}{\text{hr}} \text{ at 1 Cm}\right)$

r = Distance of arbitrary point from line source

$$b_1 = \sum_i \left(\frac{\mu}{\rho_O}\right)_i \rho_i t_i$$

$\left(\frac{\mu}{\rho_O}\right)_i$ = Total absorption coefficient of the i th material, $\frac{cm^2}{gram}$.

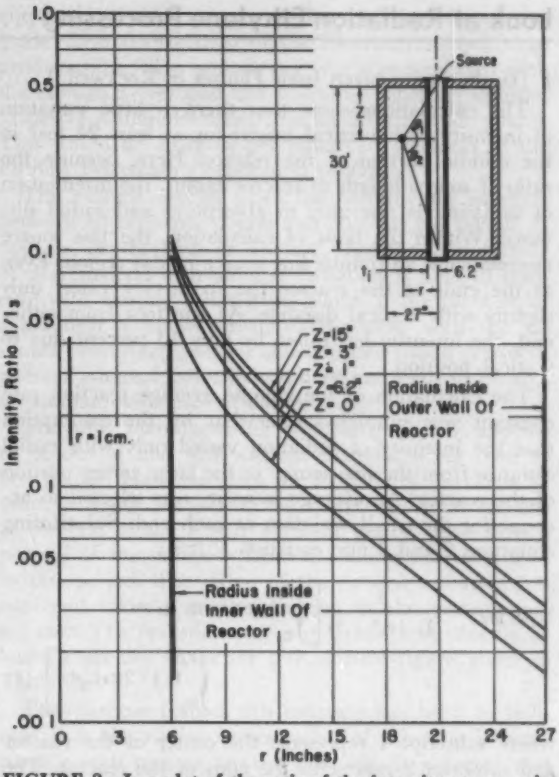

FIGURE 2—Is a plot of the ratio of the intensity at any point to the specific intensity I_S at 1 cm. from the source as a function of the radial distance r from the line source in the reactor used in this example.

ρ_i = Density of the i th absorbing material, $\frac{\text{gram}}{cm^3}$.

t_i = Thickness of i th absorbing material, cm.

θ_1, θ_2 = Angles subtended by ends of the line segments from the perpendicular from the arbitrary point to the line source.

$$F(\theta_1, b_1) = \int_{O}^{\theta_1} e^{-b_1 \sec\theta} d\theta$$

Equation (3) was evaluated for various points to determine the intensity profiles over the entire reaction volume of the annular cylindrical reactors. Figure 2 is a plot of the ratio of the intensity at any point to the specific intensity I_S at 1 cm from the source as a function of the radial distance r from the line source in the particular reactor used here. Parameters of distance Z from the inside of either end of the reactor are shown on the graph. The line source was assumed to be thirty feet long, the same as the length of the reaction volume. The values for the densities ($\rho_{steel} = 7.9$ gm/cm^3, and ρ ethylene, 100°F, 3000 psia $= .368$ gm/cm^3) and mass absorption coefficients $\left(\left(\frac{\mu}{\rho_O}\right)_{steel} = .067 \text{ cm}^2/\text{gm}^3\right)$ and $\left(\frac{\mu}{\rho_O}\right)_{ethylene} = .080 \text{ cm}^2/\text{gm}\right)$ used in the calculations of b_1 were taken from standard literature sources (9, 10). Values of the functions $F(\theta_1, b_1)$ and

$F(\Theta_2, b_1)$ were taken from Figures in Rockwell.[11]

The calculations show that there is little variation of intensity with vertical height for at least 24 feet in the middle portion of the reactor. Here, because the ratio of source length to reactor radius, the attenuation of radiation is due only to absorption and radial distance. Within the limit of calculation, the line source approximates an infinite line source in this region. Even at the ends of the reactor the intensity varies only slightly with vertical distance. At one foot from either end, the intensity has fallen by only 10 percent due to vertical position.

The calculation of the volume average reaction rate constant was simplified somewhat by the assumption that the intensity of radiation varied only with radial distance from the line source in the large center portion of the reactor. An average intensity was selected to account for the small variation at each end. Substituting equations 2 and 3 into equation 1, it is:

$$k_{(vol.\ avg.)} = \frac{1}{L\ (r_0^2 - r_1^2)}\left[\int_{r_1}^{r_o} K\, I^{.7}\, 2\pi r L_1 dr + \int_{r_1}^{r_o} K\, I^{.7}\, 2\pi r L_2 dr\right] \quad (4)$$

where subscript 1 represents the center of the reactor and subscript 2 represents the ends of the reactor. The integration is performed over the inside and outside adii of the annular reactor instead of over the reactor volume. The value for L_1 was taken to be 28 feet while L_2 was 2 feet. Equation 4 with the appropriate numerical substitution becomes

$$k_{(vol.\ avg.)} = \frac{2K(I_g r_g)^{.7}}{(30)\,(27^2 - 6.2^2)}\left[28\int_{6.2}^{27}\left\{\sum_1^2 \frac{F_1(O_1, b_1)}{r}\right\}^{.7} rdr + 2\int_{6.2}^{27}\left\{\sum_1^2 \frac{F_2(0, b_1)}{r}\right\}^{.7} rdr\right] \quad (5)$$

The two integrals were evaluated by graphical methods to give a value of $1.07 \times 10^5 Cm^{2.3}$ for the large bracketed term. The volume average reaction rate constant is:

$$k_{vol.avg.} = .0525\ K(I_g r_g)^{.7} \quad (6)$$

In selecting a suitable value for K, the experimental data of references[1,2,3,4] were considered as the basis for the design. Listed in Table 1 are the average experimentally determined reaction rate constants for the polymerization of ethylene under gamma radiation. The values given are selected values at approximately the same reaction conditions as those chosen for this design. It has been pointed out[2] from these experimental data that the reaction rate constants are some function of pressure. As shown in Table 1 the reaction rate constant increased as the reaction pressure was increased. At the assumed design reaction pressure of 3000 psi the first order reaction rate constant is taken to be 2×10^{-4}

$$\frac{1}{(hr)\ \ (kilorep/hr)^{.7}}.$$

The variation of temperature on the reaction rate was not considered as the design temperature is essentially the same as the experimental temperatures of Table 1. The assumption is made that recycle ethylene has no more capacity to react than the fresh feed. It is believed that this is not strictly true but lack of experimental data prevents a definite conclusion on this point.

It is assumed that the radiation intensity I_1, at the periphery of the elevator shaft just inside the reactor is to be 2200 kilorep per hour. At a distance one centimeter from the line source, the radiation intensity is 1.95×10^4 kilorep/hr. according to Equation 3. Substituting all pertinent values into Equation 6 the volume average reaction rate constant is calculated as .0107 hr^{-1}. If continuous reactors are operated at 3000 psi, the ethylene concentration will be 0.850 pound moles/cubic foot according to the thermodynamic data. Therefore, the rate of reaction will be $.850 \times .0107$ or 9.10×10^{-3} pound moles of ethylene converted per hour per cubic foot of reactor. As there are 453 cubic feet in each annular reactor, the polyethylene production is $453 \times 9.1 \times 10^{-3}$ or 4.12 pound moles per hour per reactor.

If the plant is operated 24 hours per day and 300 days per year, the rated capacity is

$$\frac{60 \times 10^6 \frac{lb.}{yr.}}{\left(28 \frac{lb}{lb\text{-}mole}\right)\left(300 \frac{days}{yr}\right)\left(24 \frac{hr.}{day}\right)} = 297 \frac{lb.\text{-}mol}{hr.}.$$

Therefore, the plant will need 72 individual reactors 4.5 ft. in diameter and 30 ft long.

The strength of a line source having a radiation intensity of 1.95×10^4 kilorep per hour at a distance of one centimeter may be calculated by various means[6,11]. Knowledge of the primary gamma photon energy is required. For purposes of this discussion, a value of .80 Mev per photon was assumed. This value is slightly lower than the mean photon energy from a week old M.T.R. fuel element and slightly greater than the photon energy of Cs-137.

According to Rockwell[11] the strength of source is given by the relation.

$$S_L = 4\Theta r \quad (7)$$

where S_L = source strength curies/cm for a line source and Θ = scalar flux $cm^{-2}sec^{-1}$.

The intensity of radiation I at a point 1 cm from the source may be converted to the scalar flux by the use of appropriate conversion factors. The source strengths in each reactor is,

$$S_L = (4\pi)\ (1.95 \times 10^7 \frac{rep}{hr} \text{ at 1 cm})\left(\frac{5.4 \times 10^5 \frac{Mev}{cm^2 sec}}{\frac{rep}{hr}}\right)\left(\frac{1}{.80 \frac{Mev}{disintegration}}\right)\left(\frac{1}{3.7 \times 10^{10} \frac{disintegration}{sec\ curie}}\right)$$

$$S_L = 4{,}470 \frac{curies}{cm}$$

where the rep is considered to absorb 93 ergs of energy per gram of absorbent. Since the source is 30 feet long, the total source strength per reactor is

$$S = (4{,}470)\ (30)\ (12)\ (2.54) = 4.1 \times 10^6 \text{ curies}$$

It must be pointed out that with a source of this size

the radiation intensity at the outside wall of steel reactors will be approximately $4.12 \frac{\text{kilorep}}{\text{hr}}$.

To reduce the intensity to a safe level (.05 milliroentgen per hour) for the operators of the process equipment, the reactors must be housed in caves with 4½ feet thick concrete walls. For economic reasons, ten reactors will be housed in a single cave. Each reactor will be provided with a stainless steel well in which the source may be stored during reactor shut down. The gamma radiation source will be under 30 feet of water in the well when lowered out of the reactor.

ECONOMIC ASPECTS OF RADIOPOLYMERIZATION

Fission products are not yet available commercially, but a range of costs for various types of fission products has been presented and discussed[1]. The costs of various disposal methods for fission products are also available and may be consulted.[5] The proposed plant requires a total of 295,000,000 curies. The handling and shipping problems associated with this large number of curies would be costly. Therefore, it has been assumed that the plant will be constructed very near a nuclear reactor. Cost estimations based on three possible source materials have been considered in Table 2.

Radiation Cost. In the proximity of a nuclear reactor there is a choice as to the type of source desired. Spent fuel elements could be used, or the radioactive waste fission products after proper concentration might be available. Spent fuel elements would probably be available on a rental basis while fission products could be purchased outright. It is probable that fuel elements could be obtained very cheaply. The reason is that upon removal from the reactors the elements are set aside to decay to a point where they can be handled safely.

The cost of using these elements while they decay would appear to be nominal, excluding the handling problems. Immediately upon removal from the reactor they have an extremely high activity of the order of 10^8 curies. After a period of about 80 days, the activity decreases to approximately 10^6 curies. Using perhaps 2 or 3 such elements in our reactors, an element would have to be replaced in each reactor about every two months to maintain the strength of the source. It seems unlikely that the cost of renting and handling one fuel element will be over $5,000.

In addition, the price of concentrated gross fission products should not greatly exceed 1¢ per curie, for megacurie quantities in the proximity of the reactor. Twenty percent of the .2 year half-life fission products would have to be replaced 15.6 times each year in order to prevent the source from decaying below 80 percent of its original value. The cost of buying processed Cs-137, which has an extremely long half life of 33 years, would be very high, possibly of the order of 50 cents per curie of more in the immediate future. There have been estimates, however, that Cs-137 may become available for as little as 30 cents per curie. The 50 cents per curie has been assumed in preparing Table 2.

Manufacturing Costs. At the present time the cost of manufacturing polyethylene by the Phillips low pressure process is not available in any known publication. However, a study has been made of the Phillips design and a reasonable estimate of the total investment was made. The amortization of the investment required to produce 60 million pounds per year was combined with the estimated overhead and operating expenses, in order to derive a manufacturing cost of 26 cents per pound. This would be 29 cents per pound for licensees of the Phillips Petroleum Corporation process.

The current market price for polyethylene averages between 40 cents per pound and 50 cents per pound. It appears, on the basis of Table 2, that the manufacture of polyethylene with gamma radiation is able to compete with existing commercial plants, if the plant is located near a nuclear reactor. However, with the assumed processing costs for concentrated fission products, gamma initiated polyethylene does not seem to be able to compare with present day processes.

The unit manufacturing cost using Cs-137 appears to be out of line with current manufacturing costs at first glance. However since the half life of Cs-137 is 33 years, a major portion of the radiation source remains at the end of the 5 year write-off period. Less than 5 percent of the radiation from the source has been used in this period. The value of the unused radiation has not been taken into consideration in the manufacturing cost. The realistic cost figure would undoubtedly be lower than the 48 cents per pound figure given in Table 2.

The purpose behind this estimate has been to indicate that the radiopolymerization of ethylene is comparable with present, proven methods. It is hoped that industry will pursue this process further in order to verify its expected potential.

This work was carried out in the Fission Products Laboratory of the Engineering Research Institute of the University of Michigan under a contract with the United States Atomic Energy Commission. The generous financial support of the Commission and the assistance of students in collecting data are gratefully appreciated by the authors.

NOMENCLATURE

$$b_i = \sum_i \left(\frac{\mu}{\rho_0}\right)_i \rho_i t_i$$

$$F(\Theta_1, b_1) = \int_0^{\Theta_1} e^{-b_1 \sec\Theta_d \theta}$$

d = Differential operator.
I_R = Radiation intensity at the reference point S, one centimeter from the line source, kilorep/hr.
I = Radiation intensity at the reference point S, one rep/hr.
k = Reaction rate constant of a first order reaction, (hr^{-1}).
K = Reaction rate constant which is independent of radiation intensity, hr^{-1} (krep /)$^{-.7}$.
L = Length of the source.
r = Radius at any point in the reaction, cm.
r_i = Inside radius of reaction volume, cm.
r_o = Outside radius reaction volume, cm.
S_L = Unit source strength of line source, curies/cm.
S = Total source strength, curies.
t_i = Thickness of i th absorbing material, cm.
V^R = Volume of reactor, ft^3.
ρ_i = Density of the i th absorbing material, gms/cm^3.
$(\mu/\rho^0)_i$ = Total absorption coefficient of the i th material cm^2/gm.

Look at Radiation Ethylene Processing . . .

TABLE 1—Reaction Rate Constants for the Radiation Induced Polymerization of Ethylene

Investigator	Temp. Conditions °F	Pressure Conditions psia	Radiation Conditions krep/hour	Correlation Expression	$\frac{K}{1}$ (hr) (krep/hr)$^{-.7}$	Remarks
(3)	77 — 81	175 — 315	79.6 — 84.0	First Order	1.24×10^{-6}	I.7
(2)	64 — 71	770 — 890	60 — 500	First Order	4.5×10^{-6}	I.7
(2)	64 — 71	770 — 890	60 — 500	Two Step	$K_1 = 5.3 \times 10^{-6}$	I.0
					$K_2 = 7.4 \times 10^{-6}$	I.2
					$K_1 = (1+n) = 1.58 \times 10^{-4}$	I.6
(2)	46 — 79	950 — 2300	17.5 — 54	First Order	Average 1.73×10^{-4}	I.7
(2)	60	3460	10.5	First Order	5.43×10^{-4}	Data from ref. (1) & (4)

TABLE 2—Comparison of Radiation Sources to Produce Polyethylene With Gamma Radiation

	Spent Fuel Elements	6 Mo. Old Fission Products	Cs-137
Half Life of Source	2 Days	0.2 Years	33 Years
Unit Cost of Radiation	$5000/element	$.01/curie	$.50/curie
Original Radiation Investment	$1,080,000	$2,950,000	147,500,000
Reactor Cost	2,900,000	2,900,000	2,900,000
Reactor Caves, Wells and Misc. Shielding	1,500,000	1,000,000	1,000,000
Process Equipment (Distillation Towers, Compressors, etc.)	1,500,000	1,500,000	1,500,000
Building, Piping, Utility Installations and Instruments	3,700,000	3,700,000	3,700,000
Engin. and Construc.	4,500,000	4,500,000	4,500,000
Contingencies	2,000,000	2,000,000	2,000,000
Working Capital	3,000,000	3,000,000	3,000,000
Total Investment	**$20,180,000**	**$21,550,000**	**$166,100,000**
Depreciation, Maint., Overhead at 35/of Invest. in Plant, excluding radiation	5,640,000	5,470,000	5,470,000
Taxes, Ins. and Interest at 10/of Total Invest.	2,020,000	2,160,000	16,610,000
Raw Materials	3,000,000	3,000,000	3,000,000
Radiation Replacement	2,160,000	9,200,000	0
Sales, Marketing, Administration and Packaging	2,500,000	2,500,000	2,500,000
Labor	500,000	500,000	500,000
Utilities	700,000	700,000	700,000
Annual Operating Cost	**$16,520,000**	**$23,830,000**	**$28,780,000**
Unit Manufacturing Cost	**27.5¢ per lb.**	**39.7¢ per lb.**	**48¢ per lb.**

Θ_1, Θ_2 = Angles subtended by ends of the line segments from the perpendicular from an arbitrary point to the line source.

Ψ = Scalar flux, cm^{-2} sec^{-1}.

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PART 3–Instruments

Operator's Handbook for Gasoline Plants

Prepared by plant superintendents and operating staff, this handbook makes it easy to understand the most important equipment and operations of a natural gasoline plant

Manufacturing Department, Bay Petroleum Company, A Division of Tennessee Gas Transmission Co., Houston

AUTOMATIC CONTROL is the cornerstone of the modern day gasoline plant continuous flow process. Without reliable controls present day plants could not operate. The improvement of product quality and uniformity over the years can be largely traced to the improvement of the automatic instruments.

Instruments are used to indicate, record, and/or control three process variables—temperature, pressure, and flow. Although a majority of industrial instruments are used for control purposes, many instruments are employed primarily as a guide for manual control. Recording instruments are available as a check on operations.

Design and operation information can be obtained from any good instrument manufacturer. Here are practical points about temperature, pressure, and flow instruments.

Temperature Recorders. One way to record temperature is by use of the filled thermal system. This system is a closed unit under pressure consisting of a bulb connected by capillary tubing to an element. The element is made of flattened tubing wound in a helix and located in the recorder case. When the system is filled with gas or with vapor in equilibrium with a volatile liquid, an increase in temperature causes an increase in pressure in the system. The increase in pressure uncoils the element, thus moving the pen upscale. When the system is liquid filled, an increase in temperature causes an expansion of the liquid; the helical element uncoils and moves the pen.

In any thermal system there is an error caused by transfer of heat along the neck of the bulb to the surroundings. This neck conduction error may be minimized by increasing the velocity past the bulb, by increasing the length of the neck, by decreasing the cross sectional area of the neck and by building the neck from a material of low thermal conductivity.

The heat transfer from a liquid medium to the bulb is much greater than the heat transfer from a gas medium. Therefore, shorter bulbs with shorter necks are used to measure the temperature of liquids.

Thermal Wells. Thermal wells are used when it is desirable to remove the bulb without interrupting the process, or when the fluids to be handled are corrosive. Wells are furnished in a variety of materials and can be provided with an extension for use with insulated vessels. Use of a well always slows the response of the thermal system due to the heat transfer resistance of the air film between bulb and well. This may be minimized in certain instances by placing mercury in the thermal well.

Caution! These precautions should be followed in filled thermal systems:

1. Do not twist or cut the capillary tubing.
2. Do not use the tubing as a handle to carry the instrument.
3. Never subject the bulb to temperatures in excess of the instrument range.
4. Do not bend the bulb or tubing at a sharp angle.

Friction. To operate with a maximum of accuracy, the thermal system must have all possible friction removed. To check for friction, immerse the bulb in a test bath and allow the pen to come to a final reading undisturbed, then gently tap the instrument case. If the pen jumps to a new reading, friction is present.

Excessive friction is commonly caused by dirt in the linkage connection points or by excessive pen pressure on the chart. Any dirt or gum which is present may be removed by cleaning with carbon tetrachloride. Never lubricate these joints with oil as this will serve as a collection medium for dirt.

To check the tension of the pen on the chart, press on the chart directly under the point of the pen hard enough to depress the chart about ⅛ inch. If the pen still touches the chart, the pen is bearing too heavily on the chart. Bend the pen arm away from the chart until the pen remains suspended in air when the chart is depressed. Be sure that the pen arm is not bent so much that it will not arc properly.

If excessive friction is still present and all the other sources of friction have been eliminated, the helical element should be checked. This element should have a

How to change a chart . . .

Instrument charts may be changed by following these steps:

1. Raise the pen lifter to lift the pens off the chart.
2. Pull out the chart hub. Remove the chart.
3. Wind the clock and check to be sure it is running.
4. After checking the back of the chart to see that it has the proper information written on it, place the chart over the chart hub.
5. Set the chart to the proper time.
6. Push in chart hub.
7. Lower the pen lifter and check to be sure the pens are inking.

and make pens ink . . .

Instruments may use either V-pens or box pens to transcribe the record. When these pens quit inking, they should be refilled with the proper color ink. They should not be overfilled as vibration will cause the excess ink to spill on the chart. At normal temperatures, and with ordinary records, this amount will last for several days. If the ink does not flow freely, a moistened piece of paper held against the pen point will start the flow. Box pens flow by capillary action; and if the pen remains clogged, a .007 in. diameter wire should be run through the pen to clean out deposits of dried ink.

few thousandths of an inch of end play in each direction along its axis.

Testing. The standard method of testing a thermal system in the field is to immerse the bulb in liquids of different temperatures and check with a test thermometer. Do not test in air since air currents will cause excessive temperature variations. It is not necessary to remove the thermal system to the shop for testing. It is preferable to test the system where it is installed under conditions which approach operating conditions.

A sensitive laboratory test thermometer of known accuracy should be used for checking the system. This thermometer should be immersed in the liquid to the exact point for which it is calibrated as marked on the stem. Unmarked thermometers should be immersed to a point just above the top of the mercury column. The test thermometer should have a scale which can be read more accurately than the system being tested. The instrument should be upright when being tested.

The liquid used for the testing bath is usually water for temperatures up to 210° F and oil for temperatures up to 600° F. The liquid should be thoroughly and continuously agitated to assure a uniform temperature. It is difficult to get good agitation without a mechanical agitator.

The bulb and all of the neck up to the bushing should be immersed in the test bath. Hold the bulk of the instrument and the test thermometer close together during the test. Do not allow either bulb to touch the container or a heating element. During the test, readings of the instrument and of the test thermometer should be made until successive readings show the same results. Enough time must be allowed for the bulbs to reach the liquid temperature. The type of thermal system, the length of tubing, and the bulb characteristics influence the time required. Check at least two and preferably three points at equal intervals over the range of the instrument.

Calibration Adjustments. Two adjustments are used in calibrating a thermal system: The reference adjustment and the multiplication adjustment. The reference adjustment shifts the entire scale up or down the same amount. The multiplication adjustment causes the variation in temperature to be greater in proportion to the distance from a reference point.

The reference adjustment is the most common adjustment and is done by means of the micrometer screw on the pen arm. If the instrument is a controller, the index pen should be varied the same amount to keep the central system synchronized with the measuring system.

The multiplication adjustment is changed by turning the star wheel to change the effective length of the driving lever. Lengthening the lever increases the multiplication and shortening decreases it.

PRESSURE ELEMENTS

A pressure element consists of a measuring device designed to expand or contract with changes in internal pressure. The resulting mechanical motion is transferred through linkage to a pen or control mechanism.

Basic types of pressure movements are Bourdon tubes, spirals, helicals, diaphragms, and bellows. The diaphragm and bellows expand when exposed to pressure, while the Bourdon tube, spiral, and helical types uncoil or straighten out. Both pressure and vacuum can be measured in this manner.

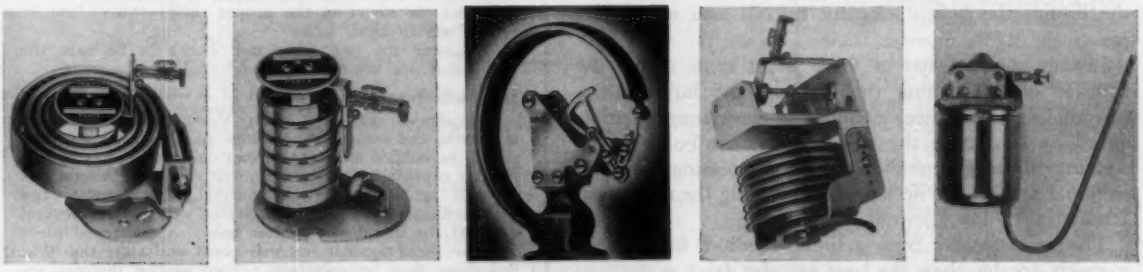
The pressure at any point below the surface of a liquid is a measure of the weight of the liquid above that point. Therefore pressure instruments can be calibrated to read directly in terms of liquid level.

Location of Pressure Tap. Pressure elements should be mounted in such a way that they will be free of shock and pulsation. Elements measuring gas pressure should be placed above the point from which the pressure is to be taken. The pressure should be taken from the top of the line or vessel to be measured. Pressure connections for measuring liquids should be in the side of the vessel or line to prevent sediment from settling in the line. Pressure connections for measuring steam or hot condensate should be made on the top of the vessel or line. This practice provides a condensate seal and prevents steam from entering the measuring mechanism.

Where operating conditions do not permit direct connection of the pressure element to the material to be measured, a third material is used as a seal. In gasoline plants ethylene glycol is usually used since it is heavier than both hydrocarbons and water and will not be lost through gravity displacement. In any sealing installation it is extremely important to remove all entrapped vapors.

FLOW RATE

All instruments within the plants that record and control the flow rate depend on the pressure drop across an orifice plate to measure this rate of flow. The orifice plate consists of a flat plate of stainless steel with a circular hole carefully machined in the exact center. This hole may be beveled in the case of small holes, in which



Spiral Helical Bourdon Diaphragm Bellows

FIGURE 13—Pressure elements expand or contract with changes in internal pressure.

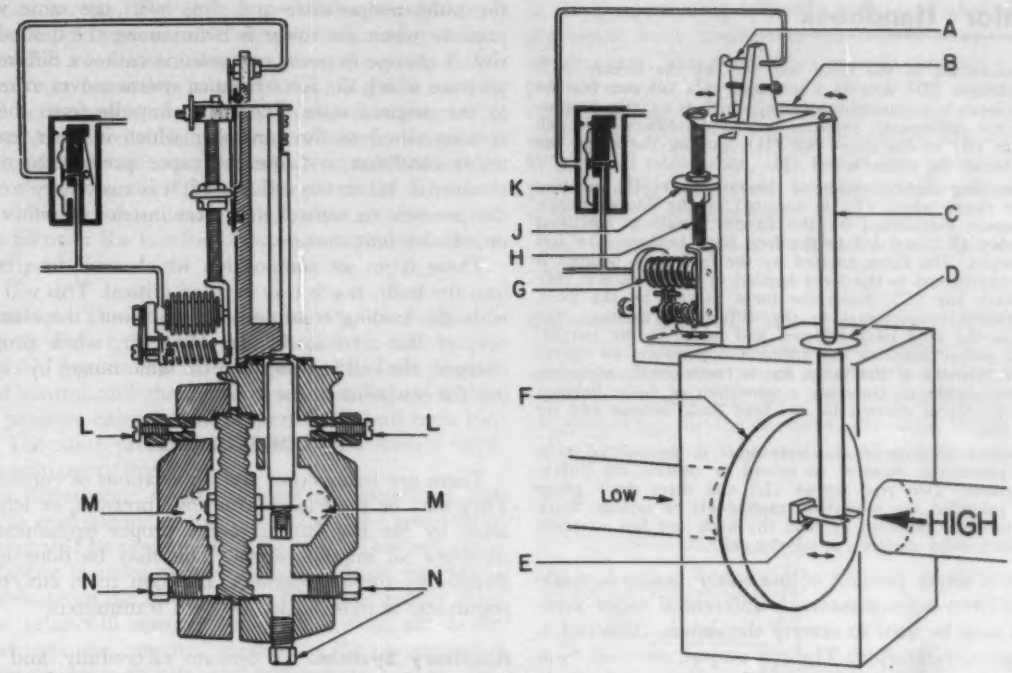


FIGURE 14—Scheme for differential pressure transmitter: It operates at remote locations on the force balance principle.

case the sharp edge should be turned toward the high pressure or upstream side. The orifice plate may be held between two flanges or may be installed in an orifice fitting which has been placed in the flow line solely for that purpose. These orifice fittings have the advantage of allowing plate changes without interruption of flow, and exact centering which greatly improves accuracy of measurement. The orifice plate installed in the line at the desired point of measurement exhibits differential pressure across the plate. This differential is related to the flow in the pipe and serves as a measure of the flow. Pressure connections are made directly to the flanges one inch on either side of the face of the orifice plate and transmitted through piping to the flow recorder or controller.

This flow recorder consists essentially of a U-tube manometer filled with mercury. The pressure differential imposed across the orifice plate causes the mercury levels to change, with the high-pressure side forcing the downstream side upward until counterbalanced by the weight of this displaced column of mercury. A float riding upon either of these columns of mercury rises and falls with varying flow rates. When the horizontal movement is transferred to rotary motion by attaching a shaft at right angles to the float and attaching a pen in turn at right angles to the shaft, a rise or fall in differential pressure can be transferred to a chart for process control purposes.

Friction is minimized by attaching the float to the shaft by chain linkage. Pressure leaks are prevented by using a plastic seal around the shaft. In some cases lubricated shafts are still used. It should be noted that although the differential pressure is measured by a mercury column, the chart is calibrated in inches of water. This change is made for ease in checking the instrument and for increased accuracy in measurement. In cases of widely fluctuating rates of flow a pulsation dampener is installed at the bottom of the manometer U-bend. Thus a restriction can be imposed to dampen or smooth out these variations in flow.

Flow Meter Calibration. There are several ways of calibrating a flow instrument. The one used in the natural gas industry consists of using a water manometer and comparing the manometer reading with the chart reading. Using this method, the instrument is vented to atmospheric pressure and the two manometers connected by a flexible hose. Then pressure gradients at different points over the range of the instrument are checked by pumping air under the same pressure into both manometers. If the readings are high or low by the same amount, the pen can be zeroed by a screw adjustment located on the pen arm. In case an ever increasing difference exists as the range of the instrument is checked, the trouble lies in the calibration of the instrument. To correct this, the linkage which connects the float to the shaft must be lengthened or shortened.

Square Root Charts. In certain applications it is desirable to have a meter read in the square root of the true differential. Using these charts, the flow rate can be obtained directly by multiplying the chart reading by a certain factor—depending on the orifice plate used. To obtain the true differential in inches of water, the chart reading should be multiplied by itself.

Transmitter. When differential pressure needs to be recorded or controlled at a remote location, a transmitter can be used. One such device operating on the force balance principle works like this (Figure 14):

The pressures are applied to opposite sides of the silicone filled twin diaphragm (F) through the high and low pressure connections as in the mercury U-tube type. Differential pressure exerts a force on the twin diaphragm capsules which is

rigidly connected to the force bar (C) by the flexure (E). The diaphragm (D) acts as a seal and as a fulcrum for the bar. The force bar transmits a force, which is exactly proportional to the differential pressure on the diaphragm, through the flexure (B) to the range bar (H), causing the range bar to pivot about the range wheel (J).

The resulting slight rotation of the range bar (H) pivoting about the range wheel (J), is detected by the flapper nozzle (A). Pressure established by the flapper nozzle is amplified by the relay (K) and led to the feed back bellows (G) and to the output. The force exerted by the feed back bellows is exactly proportional to the force applied to the range hoe (H) by the force bar (C). Since the force exerted by the force bar is exactly proportional to the differential pressure, the pressure in the feed back bellows, and hence to the output, is exactly proportional to the differential pressure. In operation the movement of the range bar is continuously adjusting the flapper nozzle to maintain a condition of force balance between the forces exerted by the feed back bellows and by the force bar.

The output pressure of the instrument is transmitted to a standard pneumatic receiver to record or control the differential pressure. Two vent screws (L) and three drain plugs (N) are provided for removing trapped air or liquids. Wire screen filters are provided at both the high and low pressure taps to keep solid matter out of the cell.

Where a single product of maximum purity is made overhead from a fractionator, a differential vapor pressure cell may be used to control the system. This cell is a pneumatic transmitter. The cell output, received by a correctional controller, may be used to vary the pressure, reboiler temperature, or reflux rate, thus controlling the process.

This cell has a reference bulb filled with the material within the tower at the desired purity. The pressure exerted by the sample is balanced against the vapor pressure of the material in the tower across a diaphragm. Both the reference sample and the tower sample are at the same temperature and thus exert the same vapor pressure when the tower is maintaining the desired purity. A change in tower composition causes a differential pressure which the force balance system moves to restore to the original state. Pneumatic impulse from the cell is transmitted to the controller which in turn resets a tower condition to cause the vapor pressure to return to normal. When the cell is used, it is customary to vary the pressure to control the tower instead of reflux rate or reboiler temperature.

There is no set composition which must be charged into the bulb; nor is tray location critical. This will vary with the loading conditions of the tower, the composition of the feed stock, etc. However, when properly charged, the cell may be used for wide ranges by changing the set point in the controller.

CONTROLLERS

There are many types and applications of controllers. They may be used to control flow, pressure, or temperature by the installation of the proper equipment for receiving an impulse signal. This may be done either directly by thermal element, Bourdon tube, etc., or by pneumatic impulse in its use with transmitters.

Auxiliary System. To operate successfully, and with low maintenance, a pneumatic controller must be adequately supplied with clean, dry air. The installation must be planned to prevent water, oil, or dirt being carried through the piping into the instrument. All tubing, pipe, and fittings must be clean inside and free from burrs. Joint compound should be applied sparingly. All joints should be checked for leaks using soap solution.

Each instrument uses a maximum of .5 to 1.0 cfm of

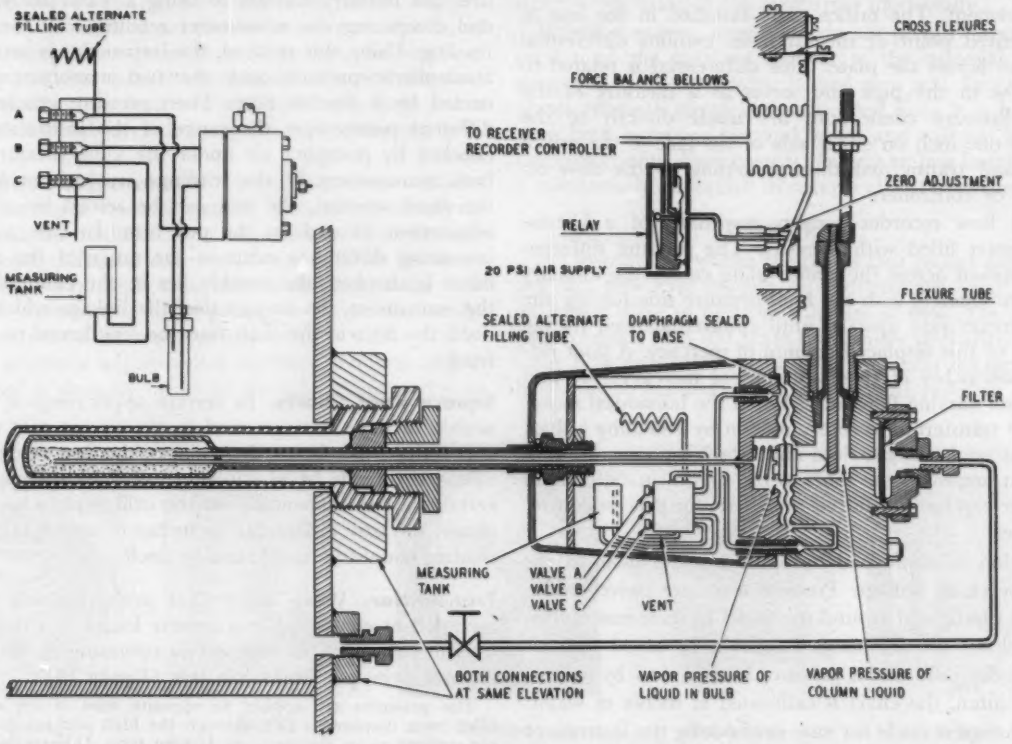


FIGURE 15—Scheme for vapor pressure cell: It can control the process pressure, reboiler temperature, or reflux rate.

air for each relay. The control mechanism should operate on a supply pressure of 17-20 psi. An air drier should be provided to eliminate water vapor and prevent freezing and rust formation in the piping. If gas is used it should be treated to remove any corrosion causing component. As a precaution against moisture, the piping from header to instruments should be connected at the top of the air header. The header should be sloped to allow drainage of moisture or oil with a valve at the lowest point in the header so that accumulations can be purged periodically.

Operation. The basic mechanism for controllers is shown in Figure 16. The scheme can be followed in Figure 17. Assume that the instrument has been on successful control and the conditions are so balanced that 8 psi pressure exists in the proportioning and reset bellows. The same pressure will exist in the control valve diaphragm motor line.

If a disturbance occurs, causing the measuring element to read higher, the top of the upright proportioning lever will be positioned to the right. This will cause the flapper to more nearly cover the nozzle, increasing the pressure on the control relay. Hence the supply valve in the relay will open wider, passing more air to the output until the increased pressure in the proportioning bellows causes it to raise the proportioning lever. This positions the flapper away from the nozzle once more.

The increased output pressure immediately starts to bleed through the adjustable reset resistance into the reset bellows. As the pressure in the reset bellows rises, the proportional lever will be lowered and the flapper will approach the nozzle. This increases the pressure on the control relay and the supply valve in the relay will pass more air to the output until the increased pressure in the proportioning bellows causes it to raise the proportioning lever, positioning the flapper away from the nozzle again. This resetting effect will continue until the pressure on the diaphragm of the control valve has increased enough to produce the required valve opening which will return the measurement to the set point. When, and only when, this occurs, the pressures in the proportioning and reset bellows become equal; and equilibrium is again restored.

All controller actions described actually occur almost simultaneously.

Derivative Control. More precise control is possible by adding derivative response to controllers. In these an adjustable restriction or resistance is inserted between the control relay and the outer proportioning bellows (disregarding, for the moment, the inner bellows).

The pressure in the proportioning bellows must be

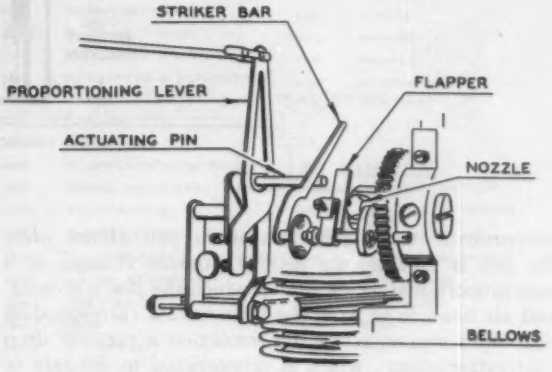


FIGURE 16—Basic mechanism for a controller.

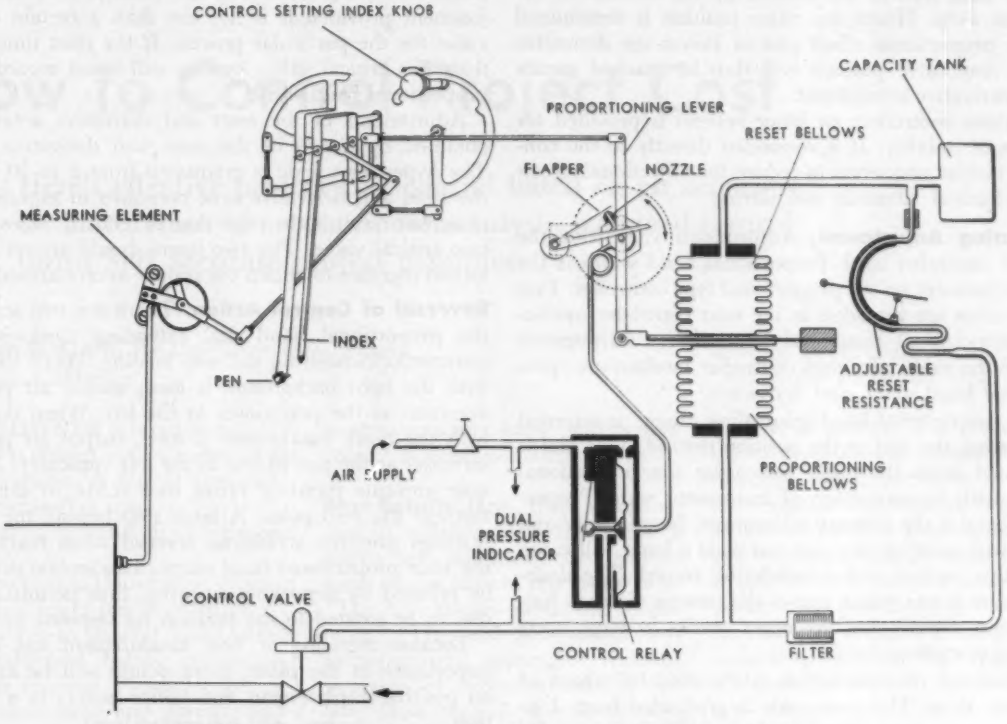


FIGURE 17—Scheme for controller with proportioning and reset bellows.

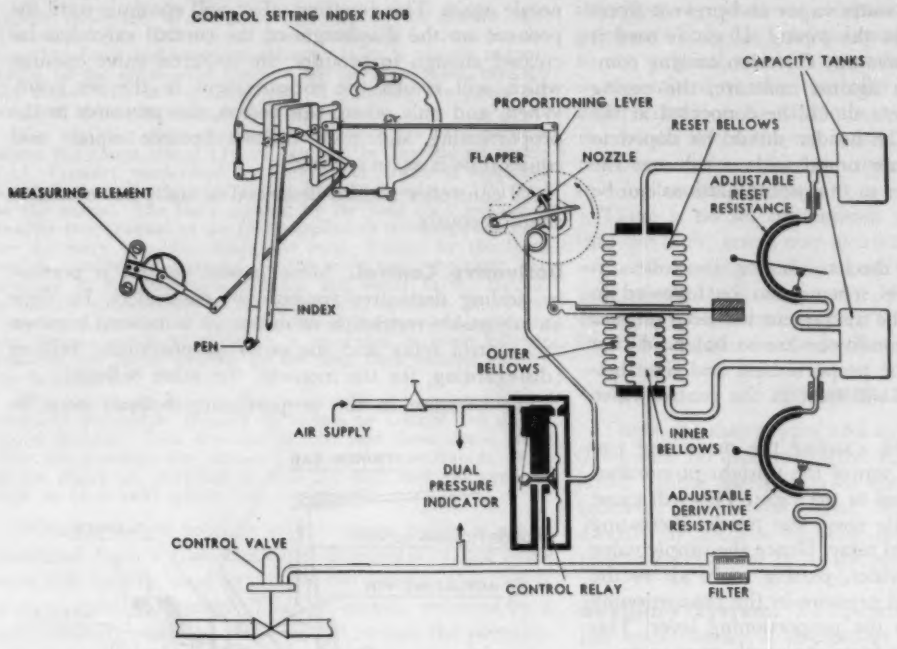


FIGURE 18—Scheme for controller with derivative control added.

proportional to the deflection of the pen. Hence when the pen is moving, the bellows pressure changes at a rate proportional to the rate at which the pen is moving, and air flows to or from the bellows at a corresponding rate. This creates across the restriction a pressure drop (derivative effect) which is proportional to the rate of pen motion. The pressure in the output line is greater or less than that in the bellows by the amount of the pressure drop. Hence the valve position is determined by the proportional effect plus or minus the derivative effect. Any valve position will thus be reached sooner when derivative is employed.

In these controllers an inner bellows is provided for reasons of stability. It is connected directly to the controller output and serves to reduce the objectional effects of mechanical vibration and jarring.

Operating Adjustment. Adjustments vary with the type of controller used. Proportional band width is the only adjustment on the proportional type controller. Two adjustments are provided in the next controller mechanism-proportional band and reset. Three adjustments feature the most advanced controller mechanism—proportional band, reset, and derivative.

The proportional band (throttling range) is adjusted by rotating the dial to the position desired. This dial is graduated from 0 to 200 indicating the proportional band width in percentage of instrument scale. Proportional band is the primary adjustment. Insufficient band width will cause cycling and too wide a band will cause insensitive control and a wandering record. The desirable value is one which causes the process to reach balance most rapidly and yet never results in large overshooting or cycling.

Adjustment of reset action is obtained by means of the reset lever. The reset scale is graduated from 1 to 50, giving the reset time in minutes. The scale graduations are also directly proportional to reset time. When the reset lever is at the bottom of the scale there is practically no resistance between the proportional and reset bellows, and the controller acts like an on-off controller. When the reset lever is at the top, there is such a long reset time that resetting action may be neglected and the controller acts like a proportional controller. Reset time does not need to be a close adjustment provided it is not less than a certain critical value for the particular process. If the reset time is less than this critical value, cycling will result regardless of proportional band width.

Adjustments of the reset and derivative actions are obtained by means of the reset and derivative liners. The hyper-reset scale is graduated from 2 to 50, giving the reset and derivative time constants in minutes. Cycling will result if the reset time is reduced below a certain critical value. The two liners should always be left locked together to obtain the proper interrelationships.

Reversal of Control Action. There are two scales on the proportional band dial extending clockwise and counterclockwise from the zero loading. When the scale with the light background is used, output air pressure *decreases* as the pen moves to the left. When the scale with the black background is used, output air pressure *increases* as the pen moves to the left (upscale). A solid stop prevents passing from one scale to the other through the zero point. A latch stop beyond the "200" readings prevents accidental reversal when marking in the wide proportional band range. This second stop may be released by depressing a spring, thus permitting the dial to be rotated to the position for opposite action.

Because metering or flow measurement has special importance in the plant, more details will be supplied on positive displacement and orifice meters in a future part.

(TO BE CONTINUED)

CHART OF ACCOUNTS

ACCOUNT NO.	DESCRIPTION
1000	SITE
1010	SURVEYING
1020	GRADING
1030	FENCING
1040	RAILROADS
1050	SIGNS
1060	ROADS
1070	PARKING LOTS
1080	BRIDGES
1090	SIDEWALKS
1100	LANDSCAPING
2000	SERVICES
2010	YARD DRAINAGE
2020	SANITARY SEWERS
2030	PROCESS SEWERS
2040	SERVICE PIPING
2050	PIPE SUPPORTS
2060	FIRE PROTECTION
2070	ELEC. DISTRIBUTION
2080	ALARM CIRCUITS
2090	YARD LIGHTING
2100	WHARFS
2110	BRIDGES
3000	BUILDING
3010	LAYOUT
3020	PERMITS
3030	GRADING
3040	EXCAVATION
3050	FORMING
3060	REINFORCING
3070	CONCRETE
3080	ANCHOR BOLTS
3090	CONCRETE FINISHING
3100	STRUCTURAL STEEL
3110	WALLS
3120	SIDING
3130	STAIRS
3140	PARTITIONS (PERMANENT)
3150	PARTITIONS (MOVABLE)
3160	ROOF (FRAMING AND DECK)
3170	ROOFING
3180	SASH & GLAZING
3190	DOORS & HDW'E
3200	SHEETROCK & ACOUSTIC TILE
3210	FLOOR COVERING
3220	PLUMBING
3230	PROCESS PIPING
3240	SEPTIC TANK
3250	SHEET METAL
3260	HEATING & VENTILATING
3270	SANDBLAST & PAINT
3280	LIGHTING & POWER
3290	TELEPHONE
3300	FURNITURE
3310	EQUIPMENT
3320	SPRINKLER SYSTEM
4000	EQUIPMENT
4010	AGITATORS
4020	CENTRIFUGES & SPRAY DRYERS
4030	COMPRESSORS & BLOWERS
4040	CONVEYORS
4050	CRYSTALLIZERS
4060	DISTILLATION EQUIP. & ABSORBERS
4070	DUST COLLECTORS
4080	EJECTORS
4090	FILTERS, DRYERS & BLENDERS
4100	FURNACES & BOILERS
4110	EVAPORATORS
4120	HOODS & PAINT BOOTHS
4130	CRUSHERS
4140	HEAT EXCHANGERS
4150	ION EXCHANGE
4160	LOADING STATIONS
4170	MATERIAL HANDLING
4180	PUMPS
4190	REACTORS
4200	REFRIGERATION
4210	MACHINE TOOLS
4220	SCREENING EQUIP.
4230	SCRUBBERS & SEPARATORS
4240	TANKS
4250	LININGS
4260	INSULATION
4270	PLATFORMS & SUPPORTS
4280	PONDS AND DIKES
4290	FOUNDATIONS
4300	INSTALLATION
4310	X-RAY & STRESS RELIEVE
4320	SANDBLAST & PAINT
4330	TESTING
5000	PIPING
5010	SUPPORTS
5020	SERVICE PIPING
5030	PROCESS PIPING
5040	INSTALLATION & TRACING
5050	SANDBLAST & PAINT
5060	TESTING
6000	INSTRUMENTATION
6010	FLOW
6020	PRESSURE
6030	TEMPERATURE
6040	LEVEL
6050	DETECTION (pH, GRAVITY, ETC.)
6060	ROTAMETERS
6070	CONTROL VALVES
6080	ORIVICE PLATES
6090	RELIEF VALVES
6100	GAUGES
6110	PIPING
6120	WIRING
6130	PANELS
6140	PAINTING
6150	TESTING
7000	ELECTRICAL
7010	CONTROL CENTER
7020	EQUIPMENT WIRING
7030	AREA LIGHTING
7040	CONDUIT SUPPORTS
7050	EXCAVATION
7060	GROUNDING
7070	PAINTING
7080	TESTING

FIGURE 1—Basic to the cost control system is this code of accounts used by Dow's Western Division.

How to Control Project Cost

Here's effective project cost control based on an accurate estimate, chart of accounts, cost analysis, standard control forms and accurate project definition

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Pittsburg, California

THE OWNER is faced with many control problems not encountered by the contractor. A few of these are:

1. Engineering cost
2. Research and development changes
3. Production Department changes
4. Insufficient bid information

Contrary to general belief, funds are authorized before contractor's bids are received. Funds are authorized, engineering and major equipment purchase made long before most contractors know that a new project is being considered.

Best Return. Here, then, is a situation in which considerable sums of money are committed by management on the basis of one factor only. "The best return on capital investment." The end product of any manufacturing agency, be it shoes, pvc pipe or petrochemicals, is dollars. How then is this investment protected and funds spent wisely in arriving at a completed project "within the prescribed limits?"

Project Engineer. The project engineer must be well informed on all financial commitments to be made from engineering through final construction. At this point enters the cost engineer. It is his responsibility to predict with the greatest accuracy possible, the probable cost of a project. On this prediction the decision is made to authorize the expenditure of funds. Admittedly, the best projects can go astray but it is a sad project engineer who cannot foresee

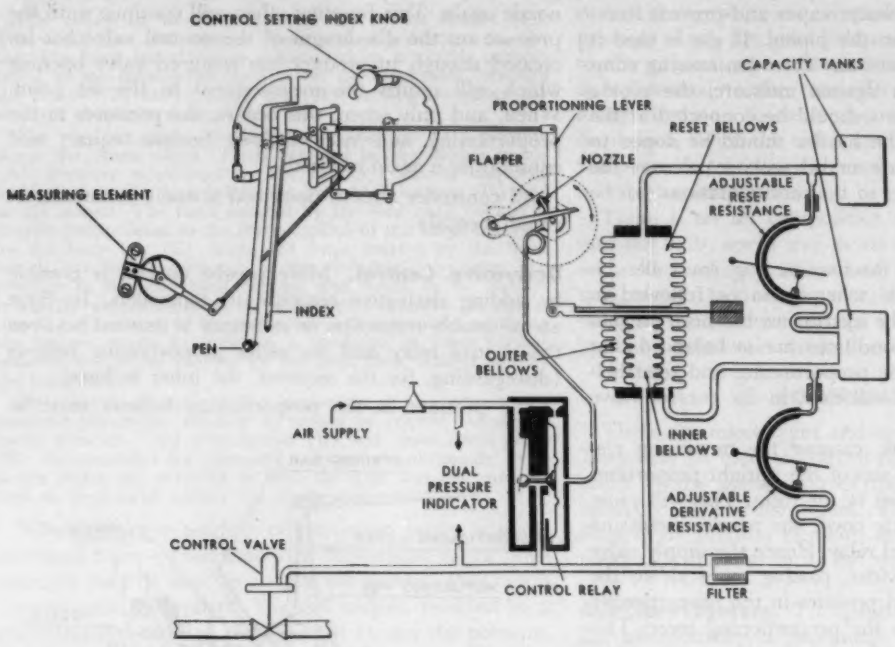

FIGURE 18—Scheme for controller with derivative control added.

proportional to the deflection of the pen. Hence when the pen is moving, the bellows pressure changes at a rate proportional to the rate at which the pen is moving, and air flows to or from the bellows at a corresponding rate. This creates across the restriction a pressure drop (derivative effect) which is proportional to the rate of pen motion. The pressure in the output line is greater or less than that in the bellows by the amount of the pressure drop. Hence the valve position is determined by the proportional effect plus or minus the derivative effect. Any valve position will thus be reached sooner when derivative is employed.

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Operating Adjustment. Adjustments vary with the type of controller used. Proportional band width is the only adjustment on the proportional type controller. Two adjustments are provided in the next controller mechanism-proportional band and reset. Three adjustments feature the most advanced controller mechanism—proportional band, reset, and derivative.

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Adjustment of reset action is obtained by means of the reset lever. The reset scale is graduated from 1 to 50, giving the reset time in minutes. The scale graduations are also directly proportional to reset time. When the reset lever is at the bottom of the scale there is practically no resistance between the proportional and reset bellows, and the controller acts like an on-off controller. When the reset lever is at the top, there is such a long reset time that resetting action may be neglected and the controller acts like a proportional controller. Reset time does not need to be a close adjustment provided it is not less than a certain critical value for the particular process. If the reset time is less than this critical value, cycling will result regardless of proportional band width.

Adjustments of the reset and derivative actions are obtained by means of the reset and derivative liners. The hyper-reset scale is graduated from 2 to 50, giving the reset and derivative time constants in minutes. Cycling will result if the reset time is reduced below a certain critical value. The two liners should always be left locked together to obtain the proper interrelationships.

Reversal of Control Action. There are two scales on the proportional band dial extending clockwise and counterclockwise from the zero loading. When the scale with the light background is used, output air pressure *decreases* as the pen moves to the left. When the scale with the black background is used, output air pressure *increases* as the pen moves to the left (upscale). A solid stop prevents passing from one scale to the other through the zero point. A latch stop beyond the "200" readings prevents accidental reversal when marking in the wide proportional band range. This second stop may be released by depressing a spring, thus permitting the dial to be rotated to the position for opposite action.

Because metering or flow measurement has special importance in the plant, more details will be supplied on positive displacement and orifice meters in a future part.

(TO BE CONTINUED)

CHART OF ACCOUNTS

ACCOUNT NO.	DESCRIPTION
1000	SITE
1010	SURVEYING
1020	GRADING
1030	FENCING
1040	RAILROADS
1050	SIGNS
1060	ROADS
1070	PARKING LOTS
1080	BRIDGES
1090	SIDEWALKS
1100	LANDSCAPING
2000	SERVICES
2010	YARD DRAINAGE
2020	SANITARY SEWERS
2030	PROCESS SEWERS
2040	SERVICE PIPING
2050	PIPE SUPPORTS
2060	FIRE PROTECTION
2070	ELEC. DISTRIBUTION
2080	ALARM CIRCUITS
2090	YARD LIGHTING
2100	WHARFS
2110	BRIDGES
3000	BUILDING
3010	LAYOUT
3020	PERMITS
3030	GRADING
3040	EXCAVATION
3050	FORMING
3060	REINFORCING
3070	CONCRETE
3080	ANCHOR BOLTS
3090	CONCRETE FINISHING
3100	STRUCTURAL STEEL
3110	WALLS
3120	SIDING
3130	STAIRS
3140	PARTITIONS (PERMANENT)
3150	PARTITIONS (MOVABLE)
3160	ROOF (FRAMING AND DECK)
3170	ROOFING
3180	SASH & GLAZING
3190	DOORS & HDW'E
3200	SHEETROCK & ACOUSTIC TILE
3210	FLOOR COVERING
3220	PLUMBING
3230	PROCESS PIPING
3240	SEPTIC TANK
3250	SHEET METAL
3260	HEATING & VENTILATING
3270	SANDBLAST & PAINT
3280	LIGHTING & POWER
3290	TELEPHONE
3300	FURNITURE
3310	EQUIPMENT
3320	SPRINKLER SYSTEM
4000	EQUIPMENT
4010	AGITATORS
4020	CENTRIFUGES & SPRAY DRYERS
4030	COMPRESSORS & BLOWERS
4040	CONVEYORS
4050	CRYSTALLIZERS
4060	DISTILLATION EQUIP. & ABSORBERS
4070	DUST COLLECTORS
4080	EJECTORS
4090	FILTERS, DRYERS & BLENDERS
4100	FURNACES & BOILERS
4110	EVAPORATORS
4120	HOODS & PAINT BOOTHS
4130	CRUSHERS
4140	HEAT EXCHANGERS
4150	ION EXCHANGE
4160	LOADING STATIONS
4170	MATERIAL HANDLING
4180	PUMPS
4190	REACTORS
4200	REFRIGERATION
4210	MACHINE TOOLS
4220	SCREENING EQUIP.
4230	SCRUBBERS & SEPARATORS
4240	TANKS
4250	LININGS
4260	INSULATION
4270	PLATFORMS & SUPPORTS
4280	PONDS AND DIKES
4290	FOUNDATIONS
4300	INSTALLATION
4310	X-RAY & STRESS RELIEVE
4320	SANDBLAST & PAINT
4330	TESTING
5000	PIPING
5010	SUPPORTS
5020	SERVICE PIPING
5030	PROCESS PIPING
5040	INSTALLATION & TRACING
5050	SANDBLAST & PAINT
5060	TESTING
6000	INSTRUMENTATION
6010	FLOW
6020	PRESSURE
6030	TEMPERATURE
6040	LEVEL
6050	DETECTION (pH, GRAVITY, ETC.)
6060	ROTAMETERS
6070	CONTROL VALVES
6080	ORIVICE PLATES
6090	RELIEF VALVES
6100	GAUGES
6110	PIPING
6120	WIRING
6130	PANELS
6140	PAINTING
6150	TESTING
7000	ELECTRICAL
7010	CONTROL CENTER
7020	EQUIPMENT WIRING
7030	AREA LIGHTING
7040	CONDUIT SUPPORTS
7050	EXCAVATION
7060	GROUNDING
7070	PAINTING
7080	TESTING

FIGURE 1—Basic to the cost control system is this code of accounts used by Dow's Western Division.

How to Control Project Cost

Here's effective project cost control based on an accurate estimate, chart of accounts, cost analysis, standard control forms and accurate project definition

William G. Clark, The Dow Chemical Company
Pittsburg, California

THE OWNER is faced with many control problems not encountered by the contractor. A few of these are:

1. Engineering cost
2. Research and development changes
3. Production Department changes
4. Insufficient bid information

Contrary to general belief, funds are authorized before contractor's bids are received. Funds are authorized, engineering and major equipment purchase made long before most contractors know that a new project is being considered.

Best Return. Here, then, is a situation in which considerable sums of money are committed by management on the basis of one factor only. "The best return on capital investment." The end product of any manufacturing agency, be it shoes, pvc pipe or petrochemicals, is dollars. How then is this investment protected and funds spent wisely in arriving at a completed project "within the prescribed limits?"

Project Engineer. The project engineer must be well informed on all financial commitments to be made from engineering through final construction. At this point enters the cost engineer. It is his responsibility to predict with the greatest accuracy possible, the probable cost of a project. On this prediction the decision is made to authorize the expenditure of funds. Admittedly, the best projects can go astray but it is a sad project engineer who cannot foresee

THE DOW CHEMICAL COMPANY
PITTSBURG, CALIFORNIA

ENGINEERING DEPARTMENT
COST ESTIMATE - BREAKDOWN

JOB NO. 5916
CHARGE
CONSTRUCTION BY DOW ☐ CONTRACTOR ☒
CLASSIFICATION B & A ☒ EXPENSE ☐

DATE Oct. 8 - 1958
PAGE 6 OF 16
PREPARED BY W. G. Clark
CHECKED BY Cwgc

ACCOUNT NO.	DESCRIPTION	UNIT	QUAN.	UNIT LABOR	UNIT MATERIAL	LABOR	MATERIAL	OTHER	TOTAL
4000	EQUIPMENT								
4060	COLUMNS								
	B-1 Batch Still								
	1956 Cost $4800	ea	1		5750	~	5750	~	5750
	B-1 Dip Pipes								
	1956 Cost $300	ea	1		360	~	360	~	360
4140	HEAT EXCHANGERS								
	H-1 Shell & Tube								
	1956 Cost $6200	ea	1		7450	~	7450	~	7450
4230	SEPARATOR								
	T-32 Phase Separator								
	1956 Cost $700	ea	1		840	~	840	~	840
4240	TANKS								
	X-11 De-Superheater	ea	1		300	~	300	~	300
4270	PLATFORMS								
	B-1 Operating Platform	ton	0.5	150	400	75	200		275
	Floor Plate	#	40	0.50	1.50	20	60		80
	Hand Railing	Lf	20	2	1.50	40	30		70
	Ladder	Lf	20	3	10	60	200		260
4300	INSTALLATION								
	B-1	ea	1	400	50	400	50		450
	H-1	ea	1	150	10	150	10		160
					SUB TOTAL	785	15250		16035

THE DOW CHEMICAL COMPANY
PITTSBURG, CALIFORNIA

ENGINEERING DEPARTMENT
COST ESTIMATE - BREAKDOWN

JOB NO. 5916
CHARGE
CONSTRUCTION BY DOW ☐ CONTRACTOR ☒
CLASSIFICATION B & A ☒ EXPENSE ☐

DATE Oct. 8 - 1958
PAGE 7 OF 16
PREPARED BY W. G. Clark
CHECKED BY WGC

ACCOUNT NO.	DESCRIPTION	UNIT	QUAN.	UNIT LABOR	UNIT MATERIAL	LABOR	MATERIAL	OTHER	TOTAL
4000	EQUIPMENT								
	SUBTOTAL PG #6					785	15250		16035
4300	INSTALLATION (cont'd)								
	T-32	ea	1	75	10	75	10		85
	X-11	ea	1	30	5	30	5		35
4260	INSULATION								
	B-1 85% MAG	#	650		3	~	~	1950	1950
4320	PAINTING								
	ALL EQUIPMENT	#	1000		0.25	~	~	250	250
4330	TESTING								
	Hydrostatic	allow				200	50		250
	NO 4000 SUB TOTAL					1090	15315	2700	18605
	SALES TAX	%	4			4	610		610
	FREIGHT	%	5			5	765		765
	CONTRACTOR OVERHEAD	%	65	46		700	~	130	830
	CONTRACTOR PROFIT	%	10	15		150	850	~	1010
	CONTINGENCY	%	15	18.10		300	1400	230	1930
	NO 4000 TOTAL					2270	18920	2560	23750
					SUB TOTAL				

FIGURE 2—This cost estimate form shows the use of the account numbers and postjng of all labor and material costs.

this condition and advise his management so that remedial action can be taken.

Effective cost control has one inescapable prerequisite. This is an exact definition of what the allocated funds are expected to provide. Once this is established, the following relatively simple tools are required:

1. An accurate estimate
2. A detailed Chart of Accounts
3. Good project cost analysis
4. Standard cost control forms
5. Accurate project definition

At Dow's Western Division, a system has been developed embodying the above and used with very satisfactory results.

The Estimate. The first step in any project is the preparation of an estimate in as much detail as possible. Figure 1 is a copy of our standard Chart of Accounts, all estimates are prepared in strict accordance with this system. Figure 2 is a copy of a portion of a recently completed estimate for an addition to an existing plant.

Chart of Accounts. The second step is to prepare a Chart of Accounts for our Accounting Department. This is the key document to a successful control system. Account numbers and values are assigned to all cost items. Project costs are segregated under the major headings of:

1. Dow purchases
2. Dow engineering
3. Contractor engineering
4. Construction contracts

4a. Change orders

5. Contingency

Figure 3 is a typical chart of accounts ready for transcribing to the control documents. Each item of controllable expenditure has its own account number. The value assigned to these items includes all anticipated cost except contingency. Contingency is carried as a separate number, as it is our management's policy that contingency shall be spent only as absolutely necessary and is not an item to be used for goldplating or project expansion. Withdrawals from contingency cannot be made to cover project changes in scope without the prior approval of management. Figure 4 is a set of cost control documents ready for initial distribution to parties concerned.

May 25, 1959

Accounting

cc:
Tabulating — Production Management
Accounting — Accounts Payable
Timekeeping — Storeroom

JOB NO. 5916 - PLANT EXPANSION

The following is a chart of accounts for the above job. Authorization No. _____ Charge No. _____:

_____	.4060	B-1	$ 6,280
	.4061	B-1 Dip Pipes	395
	.4140	H-1	8,140
	.4230	T-32	920
	.4240	X-11	330
	.4260	B-1 Insulation	1,950
	.9600	Contract	3,805
		Contingency	1,930
		Total Authorized	$ 23,750

Engineering Department

9600 Contract Breakdown

B-1 Platform	$ 1205	
Equip. Installation	1375	= $ 3,805
Painting	380	
Testing	485	

FIGURE 3—Shows that each item of controllable expenditure has its own account number so vital in controlling project costs.

The third step is a three-pronged venture involving the project engineer, clerical section and accounting department.

All documents involving financial commitments, i.e. engineering, purchase orders, contracts, change orders, etc., must bear the appropriate account number and approximate cost involved on the particular document. This is the responsibility of the project engineer.

The clerical section enters this amount in the commitment column. This is the beginning of the current cost picture. At this stage, the contingency will show at its full authorized amount in the Current Best Estimate column. As the job progresses, this amount is reduced so as to maintain approximately the same percentage relationship with the total shown under balance to be committed.

The Accounting Department processes all documents through accounting machines using the account numbers as identification. A monthly report is sent to the clerical section and these costs are entered in the "Paid to Date" column.

Cost Reviews. The project engineer reviews the cost control document on a bi-weekly basis and enters his "current best estimate." With all the available and current cost data before him, the project engineer has a clear picture of his financial status. This information enables him to spot immediately any "soft" spots and take corrective action within the scope of this authority.

Change orders are carried as a separate item on the control sheets. This insures the following action on all change orders:

1. Documentation on standard forms, bearing change order number, description of change, reason for change and signature of person or persons responsible for change.

How to Control Project Cost . . .

ENGINEERING DEPARTMENT · ESTIMATE OF COST

THE DOW CHEMICAL COMPANY
PITTSBURG, CALIFORNIA

DATE:
CHARGE:
PROJECT ENGINEER:

Job No. 5916 – Plant Expension
Summary Sheet

Amount Paid To:

ITEM	DESCRIPTION	AUTHORIZATION	TRANSFERS	REVISED AUTHORIZATION	PREVIOUS ESTIMATE	CURRENT BEST ESTIMATE	COMMITMENTS	BALANCE TO BE COMMITTED		NET (OVER) OR UNDER AUTH.
4060	B-1	6 280		6 280		5 603	4 550	1053	4 620	1660
4061	B-1 Dip Pipes	395		395		596	585	11	596	(201)
4140	H-1	8 140		8 140		8 428	8 356	72	8 428	(289)
4230	T-32	920		920		743	743	~~	743	177
4240	X-11	330		330		252	252	~~	252	78
4260	B-1 Insulation	1 950	(1950)			~~	~~	~~	~~	~~
	Total Dow Purchases	16 015		16 065		15 622	14486	1136	14 639	1426
9600	Contract	3 805	1950	5 755		4 450	4 450		4 450	1 305
	Change Orders	---	1 140	1 140		1 140	560	580	560	580
	Total Contract	3 805		6 895		5 590	5 010	580	5 010	1885
	Contingency	1 930	(1 140)	790		300	300	~~	~~	790
	Total Job Cost	23 750		23 750		21 512	19 796	1 716	19 649	4101
	TOTALS									

383-13-3C-1156

FIGURE 4—This status sheet shows the current cost picture of the project at any particular date.

2. Scrutinizing of all proposed changes in light of their necessity and impact on cost.

3. Inclusion in the proper place on the cost control forms.

The last column on the cost control sheet shows the current actual status of the project in relation to over or under expenditure. The transfer column provides a means of switching funds from one phase to another, i.e. owner purchase to contractor purchase, contractor construction to owner's construction forces, etc. All transfers are carefully scrutinized for reason and amount before being authorized.

Some phases of this program may seem somewhat restrictive upon the project engineer's ability to manage the funds as he sees fit. However, the use of this system enables carrying out the general policy of expending funds only for the specific purpose authorized. The system thus insures that changes from the schedule of expenditures in the original appropriation are approved in writing by proper authority. There is a great reluctance to fix your signature, or that of the production men, to a change order unless you are fully prepared to justify the change.

Benefits. A very important benefit of this method of control is being able to spot potential surplus at an early date. With this knowledge, management is able to authorize project expansion or inclusion of items previously considered desirable but not an absolute necessity.

Orginally presented before the American Association of Cost Engineers, Pittsburgh, Pa., June, 1959.

About the Author

William G. Clark is a senior estimator for The Dow Chemical Company's Western Division, Pittsburg, Calif. He is responsible for preparation of all the division's estimates, including preliminary studies through authorization request. Clark is also responsible for cost collection, analysis, and final cost reporting on completed jobs. With Dow since 1946, he has held various technical positions, and has been in charge of estimating for eight years. He studied mechanical engineering through International Correspondence School, and has taken courses from the University of California Extension Service.

Applied Hydrocarbon Thermodynamics

Part 13: Equilibrium Flash Vaporization Correlations for Heavy Oils Under Sub-Atmospheric Pressures

Wayne C. Edmister* and K. Keith Okamoto
California Research Corporation
Richmond, Calif.

IN THE PREVIOUS INSTALLMENT, an empirical method was presented for making vapor-liquid phase equilibria predictions for petroleum fractions at atmospheric and higher pressures. The Phase Diagram Construction Chart, Figure 12.14, was used in transforming the atmospheric pressure EFV curves to superatmospheric pressures. The straightness of the constant percent vaporized lines between atmospheric and focal pressures suggest the possibility of extrapolating these lines to find the phase conditions at subatmospheric pressures.

This extrapolation is not reliable. Separate correlations are required for predicting phase equilibrium conditions for heavy oils, such as reduced crudes and residua. The starting data for predicting the phase diagrams for heavy oils will be a vacuum TBP or ASTM assay, generally run at 10 mm absolute pressure.

From the interrelationships shown on Figure 12.1, it is evident that there are two correlation routes that may be followed in going from a 10 mm assay to an EFV at some intermediate pressure, say 50 mm. Correcting the 10 mm ASTM or TBP up to 760 mm and then using the correlations in Part 12 and extrapolating the phase diagram from 760 mm down to 50 mm is not recommended for heavy oils. The alternate method wherein the 10 mm EFV is first estimated and this is transformed up to 50 mm is the better method. For heavy gas oils, calculations by either procedure to give the same results should be provided for.

Empirical methods of predicting phase relationships in the vacuum region for high boiling petroleum fractions are presented in this installment. These are based on experimental data, some from the technical literature and some new data.

Conversion of ASTM Distillation Curves. A method has been developed relating the 10 mm ASTM D 1160 and ASTM D 158 distillations from a number of experimental data on gas oils. This method transposes the 10 mm ASTM D 1160 distillation data to a pseudo-ASTM D 1160 at atmospheric pressure by use of a vapor pressure chart (Figure 13.1). This pseudo-ASTM D 1160 is then converted to an atmospheric ASTM D 158 by use of volume percent distilled corrections and a table of stem corrections. This method has been consolidated by combining the volume percent corrections and

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TABLE 13.1—Evaluation of Figures 13.1 and 13.2 for Predicting 760 mm ASTM D 158 Distillation from 10 mm ASTM D 1160

Stock (Reference)	Vol. %	760 mm Distillation: Pseudo D 1160 via 10 mm Data and Figure 13.1	760 mm Distillation: D 158: Obs.	760 mm Distillation: D 158: Calc. Figure 13.2	760 mm Distillation: D 158: Diff. Calc.—Obs.
Gas Oil No. 1 (15)	10	680	670	671	+ 1
Gas Oil No. 2 (15)	10	562	560	578	+18
	30	682	648	652	+ 4
Gas Oil No. 3 (15)	10	562	548	560	+12
	30	657	621	630	+ 9
	50	727	682	682	0
Gas Oil No. 4 (15)	10	571	556	568	+12
	30	656	641	630	+11
	50	771	695	717	+22
Gas Oil No. 5 (15)	10	628	610	619	+ 9
	30	655	540	629	−11
	50	685	642	648	−14
	70	729	690	690	0
Gas Oil No. 6 (15)	10	542	563	542	−21
	30	690	655	658	+ 3
Gas Oil No. 7 (15)	10	514	519	516	− 3
	30	634	621	610	−11
	50	766	699	714	+15
Gas Oil No. 8 (15)	10	648	622	634	+12
	30	667	648	639	− 9
	50	962	669	654	−15
	70	731	689	683	− 6
Gas Oil No. 9 (15)	10	483	499	488	−11
	30	634	621	610	−11
	50	766	699	714	+15
Gas Oil No. 10 (15)	10	347	353	362	+ 9
	30	382	380	381	+ 1
	50	403	411	393	−18
	70	482	469	463	− 6
	90	619	578	586	+ 8
Gas Oil No. 11 (15)	10	569	566	566	− 2
	30	636	614	612	− 2
	50	674	648	638	−10
	70	720	682	674	− 8
Gas Oil No. 12 (15)	10	583	528	578	+50
	50	643	634	611	−22
Gas Oil No. 13 (15)	10	711	687	688	+ 1
Gas Oil No. 14 (15)	10	496	492	500	+ 8
	50	527	512	507	− 5
	90	572	550	544	− 6
Gas Oil No. 15 (15)	10	616	606	608	+ 2
	50	675	651	639	−12
	90	739	698	688	−10
Gas Oil No. 16 (15)	10	511	518	513	− 5
	30	550	534	535	+ 1
	50	599	548	545	+ 2
	70	598	557	559	+ 2
	90	624	592	590	− 2
Gas Oil No. 17 (15)	10	579	616	575	−41
	30	665	664	637	−27
	50	738	705	691	−14
	70	795	740	735	− 5
Gas Oil No. 18 (15)	10	484	485	489	+ 4
	30	546	533	532	− 1
	50	611	562	563	+ 1
	70	671	638	633	− 6
	90	776	712	718	+ 6
Gas Oil No. 19 (15)	10	522	532	524	− 8
	30	630	603	607	+ 4
	50	705	663	665	+ 2
Gas Oil No. 20 (15)	10	563	577	578	+ 1
	30	670	654	642	−12
	50	725	691	681	−10
Gas Oil No. 21 (15)	10	524	576	526	−50
	50	671	628	636	+ 8
	90	811	664	746	+82
Gas Oil No. 22 (15)	10	682	646	647	+ 1
Gas Oil No. 23 (15)	10	465	487	472	−15
	50	640	614	609	− 5
	90	820	751	753	+ 2
Gas Oil No. 24 (15)	10	700	668	679	+11
Gas Oil No. 25 (15)	10	573	563	570	+ 7
	50	745	694	697	+ 3
Gas Oil No. 26 (15)	10	455	466	463	− 3
	50	811	513	493	−20
	90	730	668	675	+ 7
Gas Oil No. 27 (15)	10	465	468	472	+ 4
	50	514	512	496	−16
Gas Oil No. 28 (15)	10	588	595	583	−12
	50	721	691	678	−13
Gas Oil No. 29 (15)	10	517	531	519	−12
	50	665	644	631	−13
	90	772	730	715	− 5
Gas Oil No. 30 (15)	10	583	582	580	− 2
	50	725	694	681	−13
Gas Oil No. 31 (15)	10	599	589	593	+ 4
	30	668	647	640	− 7
	50	718	665	675	−10
	70	778	719	721	+ 2
Gas Oil No. 32 (15)	10	444	452	452	0
	30	500	500	490	−10
	50	566	540	543	+ 3
	70	610	579	580	+ 1
	90	671	627	630	+ 3
Gas Oil No. 33 (15)	10	625	617	615	− 2
	30	702	671	668	− 3
	50	754	698	704	+ 6
	70	810	726	747	+21
Gas Oil No. 34 (15)	10	573	567	570	+ 3
	30	648	620	621	+ 1
	50	695	657	656	− 1
	70	730	693	683	−10
	90	811	745	746	+ 1

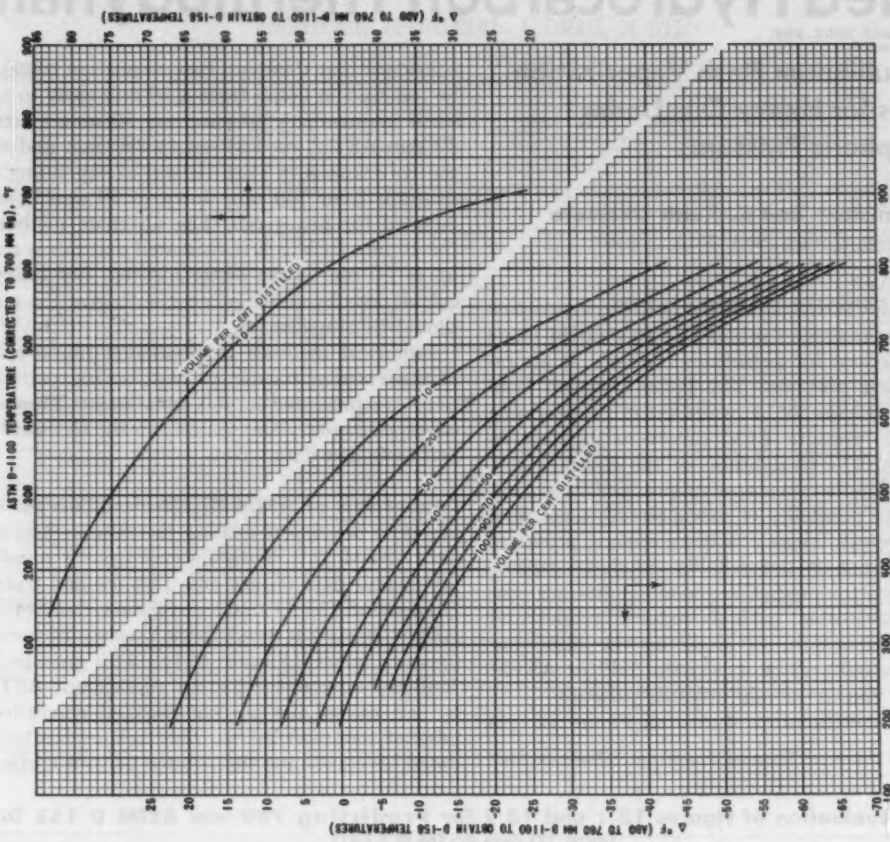

Δ °F (ADD TO 760 MM D-1160 TO OBTAIN D-158 TEMPERATURES)
ASTM D-1160 TEMPERATURE (CORRECTED TO 760 MM Hg), °F
VOLUME PER CENT DISTILLED
ASTM D 1160 TEMPERATURE (CORRECTED TO 760 MM Hg), °F
VOLUME PER CENT DISTILLED
Δ °F (ADD TO 760 MM D-1160 TO OBTAIN D-158 TEMPERATURES)

FIGURE 13.2—ASTM D-158 distillation curve from ASTM D-1160 curve at 760 mm (for gas oils).

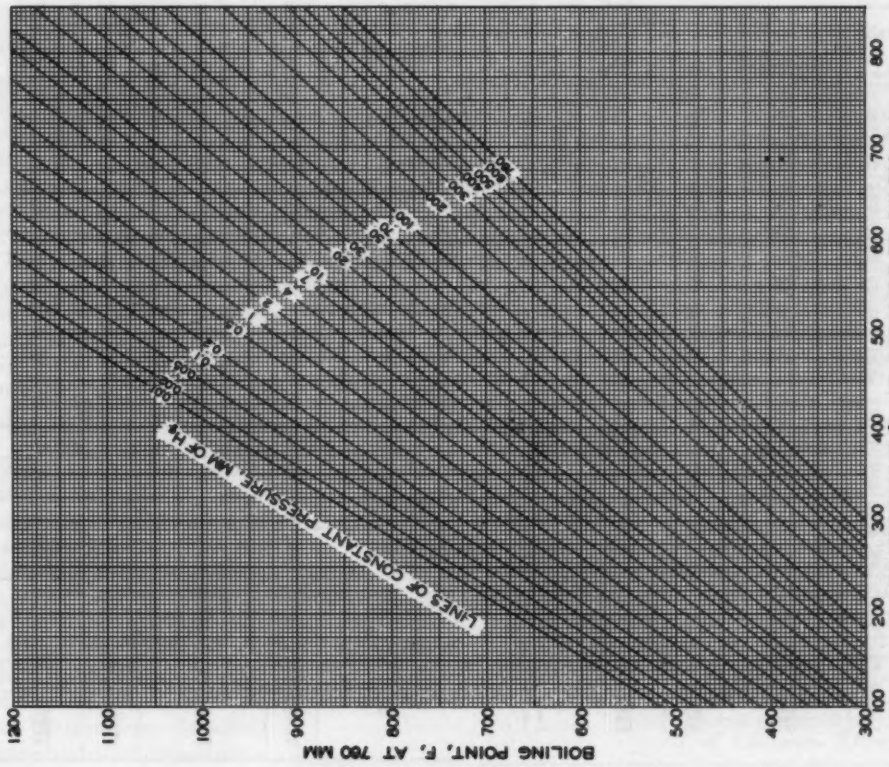


FIGURE 13.1—High temperature boiling point conversion chart for narrow cut petroleum fractions and pure hydrocarbons.

the stem corrections into a single factor and is given on Figure 13.2.

It should be emphasized that the use of this chart is limited to gas oils only. Evaluation of this correlation has been made with 104 experimental data points for 35 gas oils at the 10%, 30%, 50%, 70% and 90% points on the distillation curves. The results are shown on Table 13.1. A summary of the evaluation follows:

Chart	Maximum Deviation (°F)	Average Absolute Deviation (°F)	Number of Experimental Points		
			Deviation 0-10 °F	Deviation 11-20 °F	Deviation > 20 °F
Figures 13.1 and 13.2 (10 mm ASTM D 1160 ⟶ ASTM D 158.	50	10	68	26	10

The following example illustrates the use of Figures 13.1 and 13.2.

Example 1: Determine the ASTM D 158 distillation curve for a gas oil which has the following ASTM D 1160 distillation at 10 mm Hg pressure:

ASTM D 1160 AT 10 mm Hg PRESSURE					
0%	10%	30%	50%	70%	90%
174	337	393	434	483	542

Solution: Calculation results are tabulated below.

Step 1 Transpose 10 mm D 1160 temperatures to atmospheric pressure by use of vapor pressure Figure 13.1 to obtain D 1160 distillation at 760 mm.

Step 2 Determine Δ correction from Figure 13.2.

Step 3 Add Δ to the 760 mm D 1160 to obtain the ASTM D 158 distillation temperatures.

	Step 1		Step 2	Step 3
	ASTM D 1160			
	At 10 mm	At 760 mm	Δ	ASTM D 158
0	174	398	68	466
10	337	598	— 6	592
30	393	667	—28	639
50	434	717	—42	675
70	483	777	—57	720
90	542	850	(—73)	(777)

Phase Equilibria for Subatmospheric Pressures. With the ASTM D 1160 "Reduced Pressure Distillation

TABLE 13.2—Experimental ASTM-TBP-EFV Data for Residue Under Vacuum

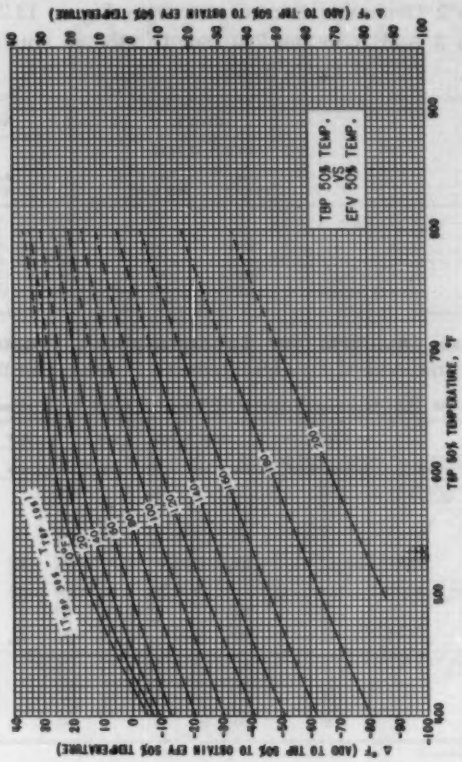
Stock (Reference)	Type of Distillation	ASTM D 1160			TBP	EFV		
	Pressure, mm Hg Volume % Off	5 mm	10 mm	100 mm	10 mm	10 mm	25 mm	100 mm
Residuum No. 1 (5)	0	118	182	275	170	275	...	400
	10	270	302	422	303	338	...	485
	20	328	350	478	357	377	...	510
	30	372	395	525	405	414	...	546
	40	420	450	577	455	452	...	585
	50	475	503	631	501	494	...	627
	60	530	560	690	553	538	...	670
	70	593	625	...	620*	586	630	...
	80	667*	695*	...	...	655	700	...
Residuum No. 2 (5)	0	256	289	350	280	450	500	562
	10	448	466	580	454	511	562	655
	20	496	523	640	532	552	605	696
	30	542	572	683	575	591	647	...
	40	582	610	...	615*	630	691	...
	50	632	660	...	660*	670	733	...
Residuum No. 3 (5)	0	280	302	410	378	395	...	533
	10	390	422	550	412	455	...	592
	20	455	484	606	480	500	...	637
	30	490	528	643	524	537	...	678
	40	532	563	...	582	574	...	...
	50	586	615	...	615*	620	...	...
	60	650	680	...	...	682	...	...

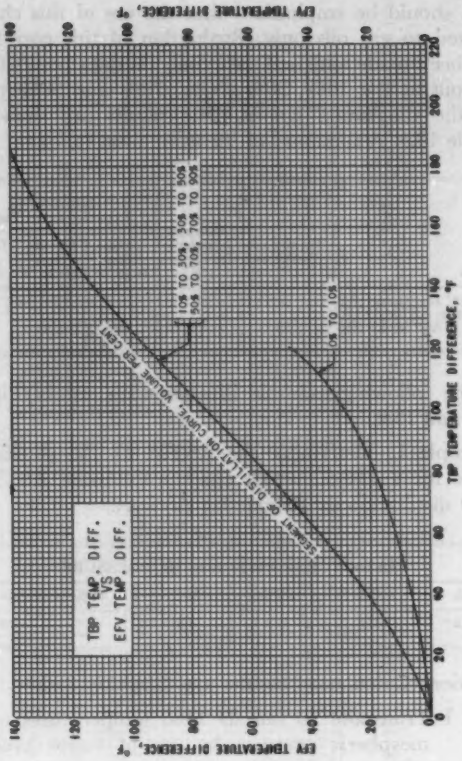
* Estimated.

TABLE 13.3—Evaluation of Empirical Correlations (Figures 13.3 Through 13.7) for Estimating 10 mm TBP and EFV

Stock (Reference)	Vol. % Distilled	Obs. 10 mm Distillations			Calc. 10 mm Distillations			TBP Diff. (Calc.—Obs.)	EFV (Calc.—Obs.)	
					TBP	EFV				
		ASTM D 1160	TBP	EFV	Figure 13.3	Figures 13.4 and 13.5	Figures 13.6 and 13.7		Figures 13.4 and 13.5	Figures 13.6 and 13.7
Resid. No. 1 (5)	0	182	170	275	160	...	268	—10	....	— 7
	10	302	303	338	293	338	329	—10	0	— 9
	30	395	405	414	391	414	402	—14	0	—12
	50	503	501	494	503	484	489	+ 2	—10	— 5
	70	625	620*	588	625	578	586	+ 5	—10	— 2
Resid. No. 2 (5)	0	269	260	450	...	...	...	....	....	....
	10	466	464	511	456	512	505	— 8	+ 1	— 6
	30	572	575	591	566	600	591	— 9	+ 9	0
	50	660	660*	670	660	660	660	0	—10	—10
Resid. No. 3 (5)	0	302	278	395	279	...	393	+ 1	....	— 2
	10	422	412	455	412	457	454	0	+ 2	— 1
	30	528	524	537	522	544	540	— 2	— 7	+ 3
	50	615	615*	620	615	610	610	0	—10	—10
Gas Oil No. 31 (5)	0	174	...	333	...	...	...	....	....	....
	10	337	317	354	322	348	356	+ 5	— 6	+ 2
	30	393	388	396	386	395	396	— 2	— 1	0
	50	434	435	422	434	422	424	— 1	0	+ 2
	70	483	483	445	483	450	452	0	+ 5	+ 7
	90	542	552	481	542	495	488	—10	+14	+ 7
Gas Oil No. 35 (5)	0	...	350	440	...	464	...	....	+24	....
	10	...	439	488	...	486	...	....	— 2	....
	30	...	489	524	...	515	...	....	— 9	....
	50	...	531	543	...	538	...	....	— 5	....
	70	...	579*	568	...	566	...	....	— 2	....
Resid. No. 4 (5)	0	...	...	...	...	...	...	....	....	....
	10	...	298	324	...	327	...	....	+ 3	....
	30	...	416	405	...	420	...	....	+15	....
	50	...	517	492	...	496	...	....	+ 4	....
Resid. No. 5 (5)	0	...	45	...	...	...	...	....	....	....
	10	...	280	314	...	311	...	....	— 3	....
	30	...	378	390	...	384	...	....	— 6	....
	50	...	478	466	...	459	...	....	— 7	....
Resid. No. 6 (5)	0	...	146	321	...	...	...	....	....	....
	10	...	356	397	...	393	...	....	— 4	....
	30	...	491	502	...	501	...	....	— 1	....
	50	...	616	601	...	601	...	....	0	....

* Estimated.





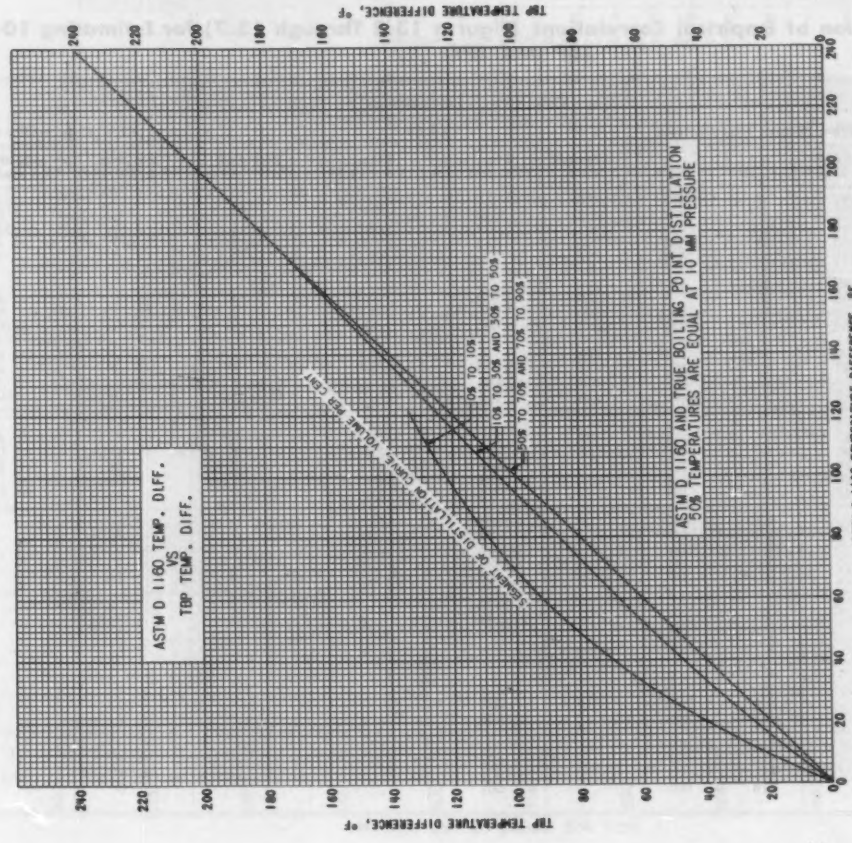

ASTM D 1160 TEMP. DIFF.
VS
TBP TEMP. DIFF.
ASTM D 1160 AND TRUE BOILING POINT DISTILLATION
50% TEMPERATURES ARE EQUAL AT 10 MM PRESSURE
10% TO 10%
10% TO 30% AND 30% TO 50%
50% TO 70% AND 70% TO 90%
ASTM D 1160 TEMPERATURE DIFFERENCE, °F
TBP TEMPERATURE DIFFERENCE, °F

FIGURE 13.3—10 mm ASTM D 1160 distillation vs. 10 mm true boiling point distillation (above).

FIGURE 13.4—10 mm TBP 50% temperature vs. 10 mm EFV 50% temperature (top right).

FIGURE 13.5—10 mm TBP temperature differences vs. 10 mm EFV temperature differences (right).

of Petroleum Products" used as a control method on heavy, high boiling petroleum fraction, it is desirable to develop correlations for predicting EFV and TBP distillations from this simple analytical distillation. The ASTM D 1160 procedure does not specify any particular operating pressure. However, most refinery operations specify a pressure of 10 mm Hg for this procedure, and therefore the bulk of the available ASTM D 1160

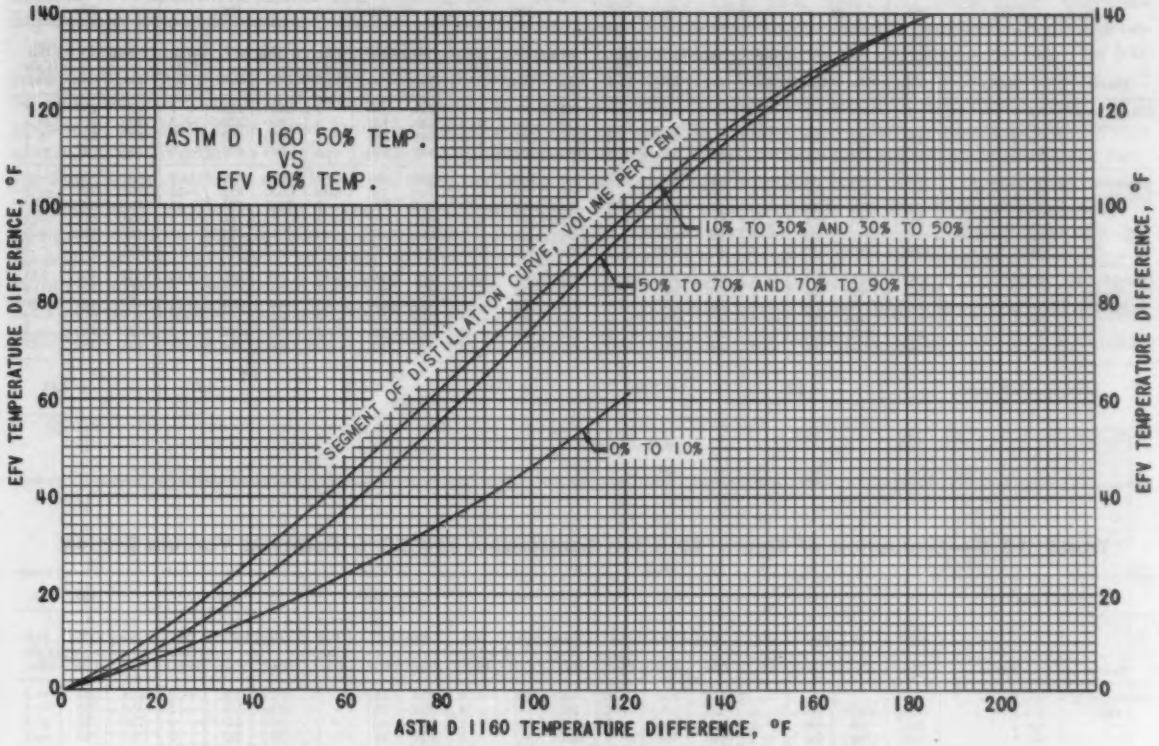

ASTM D 1160 50% TEMP.
VS
EFV 50% TEMP.
SEGMENT OF DISTILLATION CURVE, VOLUME PER CENT
10% TO 30% AND 30% TO 50%
50% TO 70% AND 70% TO 90%
0% TO 10%
EFV TEMPERATURE DIFFERENCE, °F
ASTM D 1160 TEMPERATURE DIFFERENCE, °F

FIGURE 13.6—10 mm ASTM D 1160 50% temperature vs. 10 mm EFV 50% temperature.

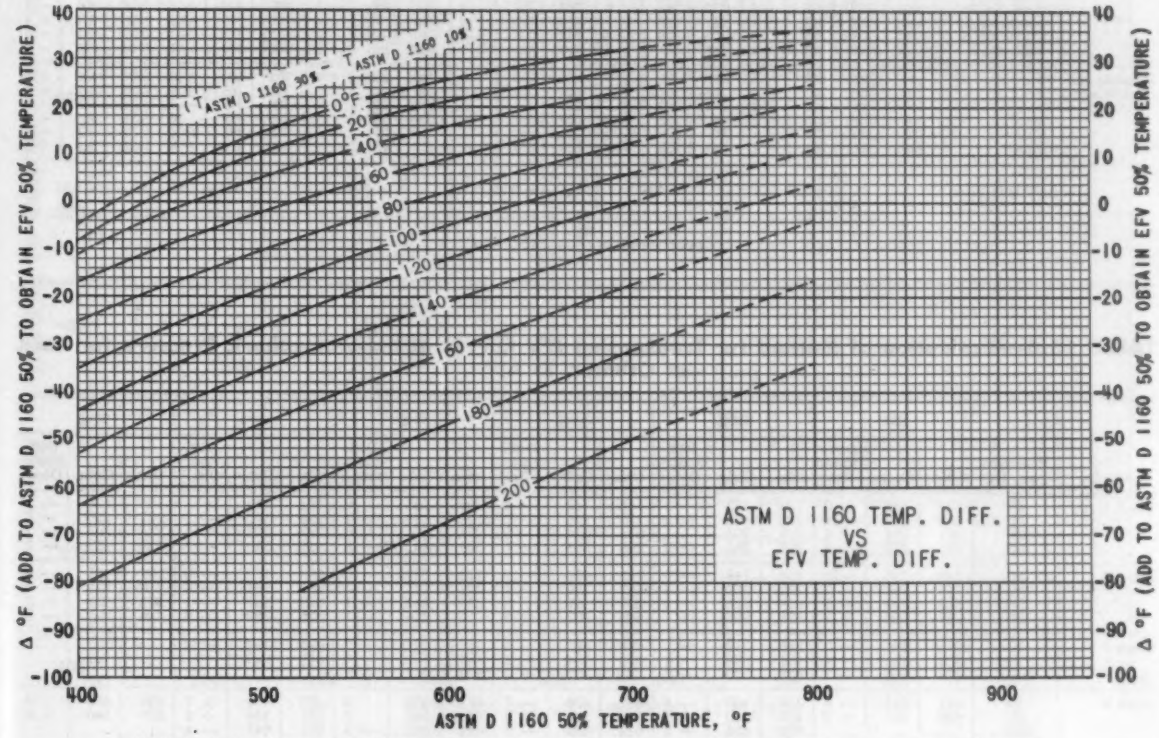


FIGURE 13.7—10 mm ASTM D 1160 temperature difference vs. 10 mm EFV temperature differences.

TABLE 13.4—Evaluation of Figure 13.8 for Transposing EFV 30% Points in Vacuum Region

Pressure mm Hg		10	25			50			100			200			400			760		
Source	Stocks	30% EFV Obs.	30% EFV Obs.	30% EFV Calc.	Diff. (Calc–Obs.)	30% EFV Obs.	30% EFV Calc.	Diff. (Calc–Obs.)	30% EFV Obs.	30% EFV Calc.	Diff. (Calc–Obs.)	30% EFV Obs.	30% EFV Calc.	Diff. (Calc–Obs.)	30% EFV Obs.	30% EFV Calc.	Diff. (Calc–Obs.)	30% EFV Obs.	30% EFV Calc.	Diff. (Calc–Obs.)
Othmer, et al (28)	No. 1	...	...	...	....	...	...	....	179	177	— 2	214	213	— 1	(257)	250	— 7	298	290	— 8
	No. 2	...	...	...	....	...	...	....	193	195	+ 2	228	232	+ 4	(268)	270	+ 2	309	313	+ 4
	No. 3	406	453	458	+ 5	498	498	0	(538)	540	+ 2	585	588	+ 3	(640)	640	0	(692)	696	+ 4
	No. 8	457	(506)	507	+ 1	546	547	+ 1	(592)	592	0	642	639	— 3	(696)	690	— 6	(754)	747	— 7
Richmond Laboratory (5)	Resid. No. 1	414	465	464	— 1	(504)	504	0	547	546	— 1	(595)	594	— 1	(650)	646	— 4	(702)	701	— 1
	Resid. No. 2	591	647	641	— 6	(688)	683	— 5	737	729	— 8	(786)	774	—12	(838)	822	—16	(890)	882	— 8
	Resid. No. 3	537	(588)	588	0	(631)	630	— 1	678	676	— 2	(728)	721	— 7	(780)	770	—10	(834)	827	— 7
	Gas Oil No. 35	525	(572)	575	+ 3	611	615	+ 4	(653)	661	+ 8	(698)	707	+ 9	(751)	756	+ 5	(800)	813	+13
	Gas Oil No. 36	(370)	(417)	420	+ 3	455	459	+ 4	(498)	500	+ 2	(543)	547	+ 4	(595)	598	+ 3	(648)	654	+ 6
	Resid. No. 5	(390)	(440)	440	0	481	480	— 1	(524)	520	— 4	(573)	568	— 5	(628)	620	— 8	(685)	677	— 8
Okamoto and Van Winkle (26, 27)	No. 1	182	(219)	224	+ 5	253	257	+ 4	284	291	+ 7	322	333	+11	366	381	+15	(406)	428	+23
	No. 2	254	(299)	299	0	335	338	+ 3	376	374	— 2	413	418	+ 5	471	471	0	(518)	522	+ 4
	No. 3	192	(238)	235	— 3	272	270	— 2	312	303	— 9	355	346	— 9	406	395	—11	(453)	443	—10
	No. 4	247	(289)	292	+ 3	325	330	+ 5	366	365	— 1	410	410	— 0	465	462	— 3	(515)	513	— 2
	No. 5	175	(215)	216	+ 1	248	248	0	287	283	— 4	328	325	— 3	375	372	— 3	(422)	418	— 4
	No. 6	224	(270)	268	— 2	302	304	+ 2	347	339	— 8	390	383	— 7	450	434	—16	(495)	484	—11
Averages of Differences			$\frac{33}{14} = 2.36$			$\frac{32}{14} = 2.29$			$\frac{62}{16} = 3.88$			$\frac{84}{16} = 5.25$			$\frac{109}{16} = 6.81$			$\frac{120}{16} = 7.50$		

Over-all average: $= \frac{440}{92} = 4.78°F$

TABLE 13.5—Evaluation of Figure 13.8 for Transposing EFV 50% Points in Vacuum Region

Pressure mm Hg		10	25			50			100			200			400			760		
Source	Stocks	50% EFV Obs.	50% EFV Obs.	50% EFV Calc.	Diff. (Calc–Obs.)	50% EFV Obs.	50% EFV Calc.	Diff. (Calc–Obs.)	50% EFV Obs.	50% EFV Calc.	Diff. (Calc–Obs.)	50% EFV Obs.	50% EFV Calc.	Diff. (Calc–Obs.)	50% EFV Obs.	50% EFV Calc.	Diff. (Calc–Obs.)	50% EFV Obs.	50% EFV Calc.	Diff. (Calc–Obs.)
Othmer, et al (28)	No. 1	...	...	...	....	156	156	0	190	186	— 4	224	224	0	(267)	258	— 9	309	301	— 8
	No. 2	(105)	(140)	140	0	173	165	— 7	201	197	— 4	236	235	— 1	(275)	273	— 2	316	315	— 1
	No. 3	451	500	500	0	(540)	540	0	(583)	585	+ 2	629	632	+ 3	(683)	683	0	(738)	741	+ 3
	No. 8	458	(509)	508	— 1	548	548	0	(592)	592	0	644	641	— 3	(692)	692	0	(750)	748	— 2
	Resid. No. 1	494	540	544	+ 4	(583)	585	+ 2	623	630	+ 7	(677)	677	0	(725)	726	+ 1	(780)	785	+ 5
	Resid. No. 2	670	(720)	719	— 1	(762)	762	0	(805)	806	+ 1	(847)	848	+ 1	(895)	895	0	(952)	952	0
	Resid. No. 3	620	(672)	670	— 2	(712)	712	0	762	757	— 5	(807)	801	— 6	(860)	848	—12	(910)	906	— 4
	Gas Oil No. 35	543	(592)	593	+ 1	631	635	+ 4	(680)	680	0	(725)	725	0	(778)	775	— 3	(828)	832	+ 4
	Gas Oil No. 36	(382)	(431)	431	0	472	470	— 2	(514)	511	— 3	(560)	558	— 2	(612)	611	— 1	(668)	667	— 1
	Resid. No. 5	(466)	(516)	516	0	557	556	— 1	(600)	601	+ 1	(650)	648	— 2	(700)	699	— 1	(758)	756	— 2
Okamoto and Van Winkle (26) (27)	No. 1	199	(238)	233	— 5	268	276	+ 8	301	310	+ 9	340	352	+12	382	402	+20	(427)	452	+25
	No. 2	275	(318)	321	+ 3	355	361	+ 6	395	397	+ 2	430	442	+12	486	495	+ 9	(535)	547	+ 9
	No. 3	208	(250)	252	+ 2	288	287	— 1	328	321	— 7	370	364	— 6	422	415	— 7	(474)	465	— 9
	No. 4	269	(313)	315	+ 2	350	355	+ 5	390	391	+ 1	434	435	+ 1	488	488	0	(531)	540	+ 3
	No. 5	192	(232)	235	+ 3	265	267	+ 2	303	302	— 1	341	344	+ 3	388	394	+ 6	(433)	442	+ 9
	No. 6	254	(300)	301	+ 1	333	338	+ 5	375	375	0	422	419	— 3	480	472	— 8	(522)	523	+ 1
Average of Differences			$\frac{25}{15} = 1.67$			$\frac{42}{16} = 2.60$			$\frac{47}{16} = 2.94$			$\frac{47}{16} = 2.94$			$\frac{79}{16} = 4.94$			$\frac{88}{16} = 5.50$		

Over-all average $= \frac{328}{95} = 3.5°F$

TABLE 13.6—Evaluation of Method for Transposing EFV Curves at Subatmospheric Pressure for Data of Othmer, Et Al[28]

		IBP			10%			30%			50%			70%			90%		
Stocks	Pressure mm Hg	Obs.	Calc	Diff. (Calc–Obs.)	Obs.	Calc	Diff. (Calc–Obs.)	Obs.	Calc	Diff. (Calc–Obs.)	Obs.	Calc	Diff. (Calc–Obs.)	Obs.	Calc	Diff. (Calc–Obs.)	Obs.	Calc	Diff. (Calc–Obs.)
Stock 1	50	121	121	0	134	133	— 1	148	146	— 2	156	156	0	164	165	+ 1	175	176	+ 1
	100	152	151	— 1	166	163	— 3	179	176	— 3	190	186	— 4	198	195	— 3	207	206	— 1
	200	191	189	— 2	202	201	— 1	214	214	0	224	224	0	233	233	0	246	244	— 2
	760	275	272	— 3	287	284	— 3	298	291	— 7	309	301	— 8	317	310	— 7	328	321	— 7
Stock 2	50	148	136	—12	156	146	—10	165	157	— 8	172	165	— 7	178	172	— 6	183	180	— 3
	100	175	168	— 7	182	178	— 4	193	189	— 4	201	197	— 4	208	204	— 4	216	212	— 4
	200	208	206	— 2	218	216	— 2	227	227	0	236	235	— 1	243	242	— 1	251	250	— 1
	760	283	286	+ 3	295	296	+ 1	309	307	— 2	316	315	— 1	325	322	— 3	336	330	— 6
Stock 3	10	287	284	— 3	350	349	— 1	408	405	— 3	451	451	0	495	498	+ 3	...	...	...
	25	338	334	— 4	401	398	— 3	453	454	+ 1	500	500	0	549	548	— 1	...	...	...
	200	473	466	— 7	533	530	— 3	584	586	+ 2	629	632	+ 3	...	...	...	...	...	...
Stock 8	10	447	442	— 5	454	450	— 4	457	456	— 1	458	458	0	463	464	+ 1	490	490	0
	50	528	530	+ 2	537	540	+ 3	546	546	0	548	548	0	551	554	+ 3	576	580	+ 4
	200	...	...	...	632	634	+ 2	642	639	— 3	644	641	— 3	651	647	— 4	...	...	...

data for this correlation was at 10 mm Hg.

Recently, Paulsen[80] published an empirical method of predicting the subatmospheric EFV curves for reduced crudes. However, this method is not entirely satisfactory because it is somewhat tedious and requires the 5 mm Hg absolute Engler distillation data.

The atmospheric three-way correlations are not applicable to heavy stocks or residua. These stocks must be distilled under reduced pressures because a large portion of the stock boils above cracking temperature of about 700°F. In order to develop distillation correlations for these stocks, vacuum distillation data are necessary.

There were available only a few sets of completely adequate experimental distillation data at low pressures on heavy stocks. In order to augment these meager data, rather complete distillations (ASTM D 1160, TBP, EFV) were obtained on three heavy stocks at subatmospheric pressures. These new experimental data are presented in Table 13.2. These new data plus published data formed the basis for the correlations presented here.

The three-way correlation relating the ASTM D 1160, TBP, and EFV at 10 mm Hg are shown as Figures 13.3, 13.4, 13.5, 13.6, and 13.7. These charts correlate the 50% temperatures and the temperature differences for various segments of the distillation curves. The low temperature range of the 10 mm 50% correlations and the high temperature range of the atmospheric 50% correlations overlap each other by about 125°F. In this region of overlap these two sets of correlations are consistent. Thus, for stocks which fall in this overlap region, either the atmospheric or 10 mm 50% correlations may be used to give the same results. These charts were developed from data on five heavy stocks, including a heavy gas oil and four residua.

These correlations have been compared with available experimental data on heavy stocks and the distribution

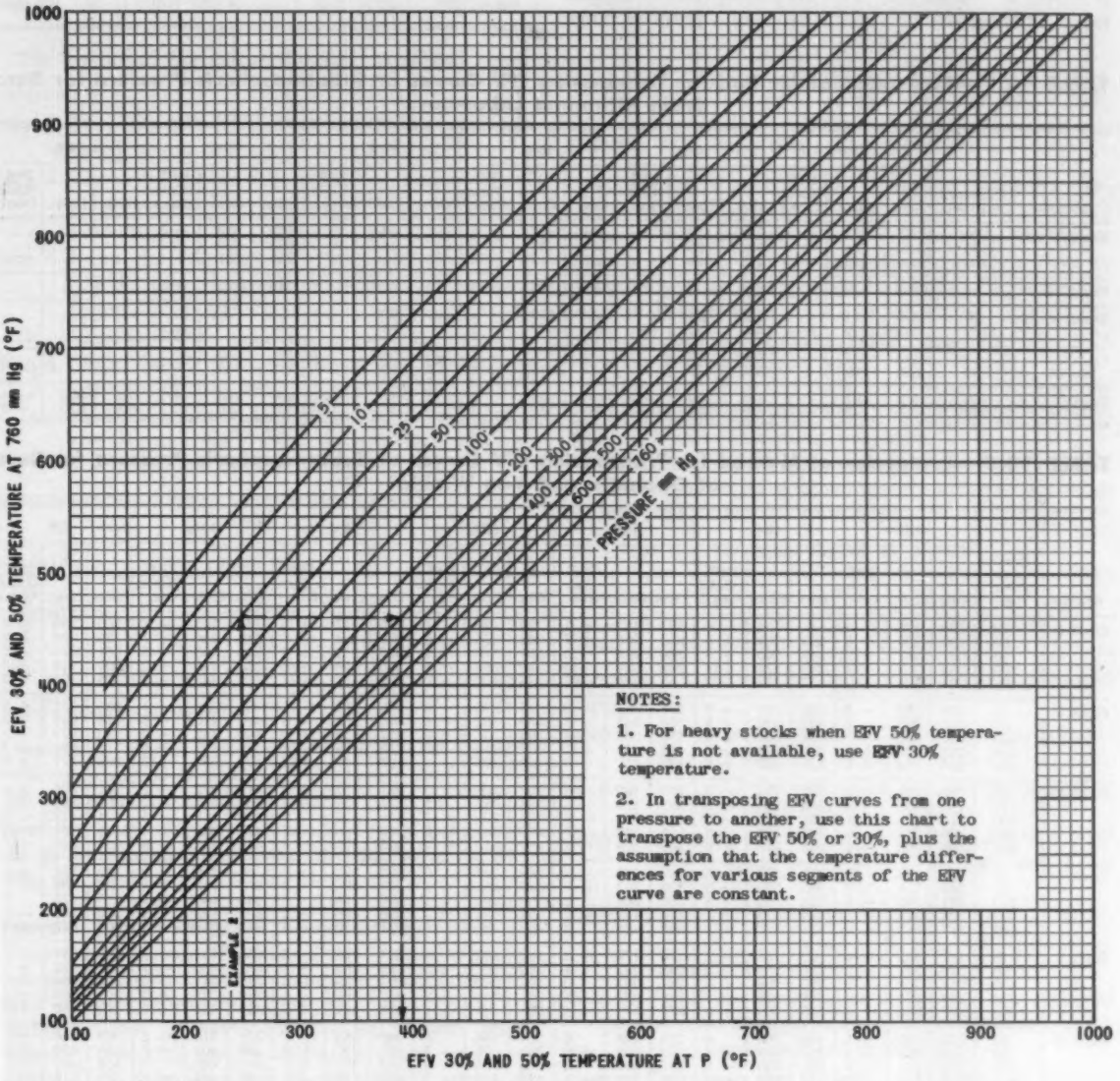

EFV 30% AND 50% TEMPERATURE AT 760 mm Hg (°F)
EFV 30% AND 50% TEMPERATURE AT P (°F)
PRESSURE mm Hg
5
10
25
50
100
200
300
400
500
600
760
NOTES:
1. For heavy stocks when EFV 50% temperature is not available, use EFV 30% temperature.
2. In transposing EFV curves from one pressure to another, use this chart to transpose the EFV 50% or 30%, plus the assumption that the temperature differences for various segments of the EFV curve are constant.
EXAMPLE

FIGURE 13.8—Effect of pressure on the 30% and 50% point temperatures on the vacuum EFV.

of the deviations and maximum deviations are tabulated below. Details of this evaluation are given in Table 13.3.

Chart	Maximum Deviation (°F)	Average Absolute Deviation (°F)	Number of Experimental Points		
			Deviation 0-10 °F	Deviation 11-20 °F	Deviation >20 °F
Figure 13.3 (ASTM D 1160 ⟶ TBP)	14	5	16	1	0
Figures 13.4 and 13.5 (TBP ⟶ EFV)	24	6	26	2	1
Figures 13.6 and 13.7 (ASTM D 1160 ⟶ EFV)	12	5	16	1	0

Effect of Pressure on EFV 30% and 50% Points in the Vacuum Region. A correlation has been developed for the temperature-pressure relationship of the EFV 30% and 50% points in the vacuum region and is shown as Figure 13.8. This correlation was developed from experimental EFV data covering a pressure range of 5 mm to 760 mm Hg and included 16 petroleum fractions ranging from a 52° API naphtha to a 11° API residuum.

Figure 13.8 has been evaluated for predicting the EFV 30% and 50% points and for transposing the EFV curves in the vacuum region. Details of this evaluation are given in Tables 13.4 and 13.5. The distribution of the deviations and maximum deviations from available experimental data are summarized below in the first two lines:

Chart	Maximum Deviation (°F)	Average Absolute Deviation (°F)	Number of Experimental Points		
			Deviation 0-10 °F	Deviation 11-20 °F	Deviation >20 °F
Figure 13.8 (Applied to EFV 30% Point)	23	5	83	8	1
Figure 13.8 (Applied to EFV 50% Point)	25	4	90	4	1
Figure 13.8 plus assumption of constant EFV slopes for transposing EFV curves in vacuum region	25	4	319	15	4

TABLE 13.7—Evaluation of Method for Transposing EFV Curves at Subatmospheric Pressure for Data From Richmond Laboratory[6]

Stocks	Pressure mm Hg	IBP			10%			30%			50%			70%			90%		
		Obs.	Calc.	Diff. (Calc. Obs.)	Obs.	Calc.	Diff. (Calc. Obs.)	Obs.	Calc.	Diff. (Calc. Obs.)	Obs.	Calc.	Diff. (Calc. Obs.)	Obs.	Calc.	Diff. (Calc. Obs.)	Obs.	Calc.	Diff. (Calc. Obs.)
Resid. No. 1	10	275	274	— 1	338	343	+ 5	414	417	+ 3	494	494	0	588	585	— 3	...	...	...
	25	320	324	+ 4	392	393	+ 1	464	467	+ 2	540	544	+ 4	630	635	+ 5	...	...	...
	100	400	410	+10	473	479	+ 6	547	553	+ 6	623	630	+ 7	712	721	+ 9	...	...	...
Resid. No. 2	10	450	452	+ 2	511	513	+ 2	591	595	+ 4	670	670	0	765	773	+ 8	...	...	...
Resid. No. 3	10	395	391	— 4	455	451	— 4	537	536	— 1	620	620	0	...	...	...	...	...	...
	100	533	529	— 4	592	589	— 3	678	673	— 5	762	757	— 5	...	...	...	...	...	...
Gas Oil No. 35	10	440	437	— 3	488	487	— 1	524	523	— 1	543	543	0	568	566	— 2	...	...	...
	50	523	529	+ 6	576	579	+ 3	611	615	+ 4	631	635	+ 4	652	658	+ 6	...	...	...
Gas Oil No. 36	50	410	407	— 3	434	429	— 5	456	453	— 3	472	470	— 2	488	485	— 3	510	505	— 4
	250	515	512	— 3	535	534	— 1	560	558	— 2	578	575	— 3	591	590	— 1	609	610	+ 1

TABLE 13.8—Evaluation of Method for Transposing EFV Curves at Subatmospheric Pressure for Data of Okamoto and Van Winkle[27]

Stocks	Pressure mm Hg	IBP			10%			30%			50%			70%			90%			EP		
		Obs.	Calc.	Diff. (Calc. Obs.	Obs.	Calc.	Diff. (Calc. Obs.)	Obs.	Calc.	Diff. (Calc. Obs.)	Obs.	Calc.	Diff. (Calc. Obs.)	Obs.	Calc.	Diff. (Calc. Obs.)	Obs.	Calc.	Diff. (Calc. Obs.)	Obs.	Calc.	Diff. (Calc. Obs.)
Stock 1	10	130	126	— 4	154	154	0	182	183	+ 1	199	199	0	216	217	+ 1	241	242	+ 1	260	259	— 1
	50	197	203	+ 6	223	231	+ 8	253	260	+ 7	268	276	+ 8	276	294	+ 7	312	319	+ 7	329	336	+ 7
	100	227	237	+10	257	265	+ 8	284	294	+10	301	310	+ 9	320	328	+ 8	348	353	+ 5	364	370	+ 6
	200	265	279	+14	293	279	+14	322	336	+14	340	352	+12	360	370	+10	385	395	+10	399	412	+13
	400	304	329	+25	337	357	+20	366	386	+20	382	402	+20	398	420	+22	422	445	+23	439	462	+23
Stock 2	10	184	179	— 5	222	227	+ 5	254	257	+ 3	275	275	0	298	297	— 1	331	330	— 1	355	357	+ 2
	50	263	265	+ 2	305	309	+ 4	335	343	+ 8	355	361	+ 6	377	383	+ 6	410	416	+ 6	438	443	+ 5
	100	302	301	— 1	346	349	+ 3	376	379	+ 3	395	397	+ 2	417	419	+ 2	450	452	+ 2	476	479	+ 3
	200	342	346	+ 4	385	394	+ 9	413	424	+11	430	442	+12	453	464	+11	488	497	+ 9	516	524	+ 8
	400	390	399	+ 9	442	447	+ 5	471	477	+ 6	486	495	+ 9	506	517	+12	538	550	+12	568	577	+ 9
Stock 3	10	163	158	— 5	174	172	— 2	192	192	0	208	208	0	237	232	— 5	277	272	— 5	301	305	+ 4
	50	240	237	— 3	253	251	— 2	272	271	— 1	288	287	— 1	314	311	— 3	352	351	— 1	383	384	+ 1
	100	278	271	— 7	292	285	— 7	312	305	— 7	328	321	— 7	352	345	— 7	390	385	— 5	424	418	— 6
	200	320	314	— 6	334	328	— 6	355	348	— 7	370	364	— 6	396	388	— 8	437	428	— 9	471	461	—10
	400	369	365	— 4	385	379	— 6	406	399	— 7	422	415	— 7	445	439	— 6	488	479	— 9	522	512	—10
Stock 4	10	170	163	— 7	210	207	— 3	247	246	— 1	269	269	0	293	293	0	326	326	0	349	352	+ 3
	50	247	249	+ 2	285	293	+ 8	325	332	+ 7	350	355	+ 5	375	380	+ 5	408	413	+ 5	433	439	+ 6
	100	281	285	+ 4	328	329	+ 1	366	368	+ 2	390	391	+ 1	416	416	0	448	449	+ 1	475	475	0
	200	324	329	+ 5	372	373	+ 1	410	412	+ 2	434	435	+ 1	458	460	+ 2	491	493	+ 2	520	519	— 1
	400	377	382	+ 5	424	426	+ 2	465	465	0	488	488	0	511	513	+ 2	543	546	+ 3	568	572	+ 4
Stock 5	10	147	143	— 4	160	158	— 2	175	177	+ 2	192	192	0	211	209	— 2	234	231	— 3	248	248	0
	50	216	218	+ 2	230	233	+ 3	248	252	+ 4	265	267	+ 2	283	284	+ 1	307	306	— 1	322	323	+ 1
	100	254	253	— 1	267	268	+ 1	287	287	0	303	302	— 1	321	319	— 2	341	341	0	359	358	— 1
	200	292	295	+ 3	308	310	+ 2	328	329	+ 1	341	344	+ 3	357	361	+ 4	380	383	+ 3	398	400	+ 2
	400	337	345	+ 8	355	360	+ 5	375	379	+ 4	388	394	+ 6	402	411	+ 9	422	433	+11	440	450	+10
Stock 6	10	152	153	+ 1	185	185	0	224	224	0	254	254	0	286	283	— 3	321	319	— 2	345	346	+ 1
	50	234	237	+ 3	265	269	+ 4	302	308	+ 6	333	338	+ 5	364	367	+ 3	398	403	+ 5	425	430	+ 5
	100	279	274	— 5	307	306	— 1	347	345	— 2	375	375	0	403	404	+ 1	440	440	0	468	467	— 1
	200	319	318	— 1	352	350	— 2	390	389	— 1	422	419	— 3	451	448	— 3	487	484	— 3	518	511	— 7
	400	370	368	— 2	407	403	— 4	450	442	— 8	480	472	— 8	507	501	— 6	545	537	— 8	572	564	— 8

By use of the temperature-pressure relationship given in Figure 13.8 for the EFV 50% and the assumption that the slopes of the EFV curve are constant in the subatmospheric pressure range, the EFV curve can be satisfactorily transposed from one pressure to another. This assumption of constant EFV slope in the vacuum region is fully justified, based on the excellent agreement of this method of transposing the EFV curves with experimental data.

Transposition of EFV curves by this method has been evaluated over a pressure range of 10-760 mm Hg. The detailed results are shown in Tables 13.6, 13.7, and 13.8 and summarized in the third line above.

The following two examples illustrate the use of Figure 13.8.

Example 2: Determine the 10 mm EFV curve for a petroleum fraction which has the following 760 mm EFV characteristics.

Vol. % Off.....	0	10	30	50	70	90	100
Temp. °F.....	440	492	518	538	558	590	615

The results of the calculations are tabulated below.

Solution:

Step 1 The 760 mm EFV temperatures for the indicated points are tabulated in Column 2.

Step 2 The temperature differences between indicated points on the 760 mm EFV curve are shown in Column 3.

Step 3 From the 760 mm EFV 50% temperature of 538°F, the 10 mm EFV 50% temperature is found from the correlation given in Figure 13.8 as 268°F.

Step 4 Since the EFV curve slopes can be assumed constant in the vacuum region, the 10 mm EFV curve is obtained by subtracting and adding to the 10 mm EFV 50% temperature, the differences found in Step 2.

Vol. % Off	Step 1 760 mm EFV Temp. °F	Step 2 Diff. °F	Step 4 10 mm EFV Temp. °F
0	440		170
		52	
10	492		222
		26	
30	518		248
		20	
50	538		268*
		20	
70	558		288
		32	
90	590		320
		25	
100	615		345

* From correlation on Figure 13.8.

Example 3: For a petroleum fraction with an EFV 50% temperature of 250°F at 25 mm Hg, find its EFV 50% temperature at 300 mm Hg.

Solution: Enter Figure 13.8 at 250°F on the abscissa and follow dashed lines and arrows and locate the EFV 50% temperature at 300 mm Hg as 390°F.

Vacuum Phase Diagram Construction. Phase diagrams for petroleum fractions above atmospheric pressure can be constructed satisfactorily by use of the focal point method shown on Figure 12.14 and 12.15. This method cannot be extended into the vacuum region without introducing considerable error. However, experimental EFV data show that in the vacuum region the parameters of constant per cent vaporized are straight lines on a log P vs 1/T plot. Therefore, the phase diagram can be constructed in the vacuum region, if one set of EFV data is available or can be predicted at any pressure between 760 mm and 10 mm Hg. This can be accomplished by transposing the known EFV data to another pressure in the vacuum region and joining the points of constant percent vaporized as straight lines on a log P vs 1/T plot.

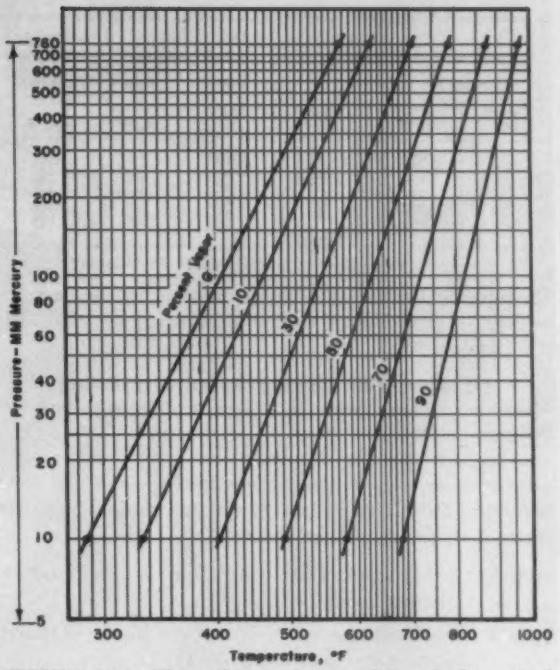


FIGURE 13.9—Phase diagram for a residium in Example 5.

Figure 13.9 illustrates the phase diagram construction for subatmospheric pressures. The following examples show how the calculations are made.

Example 4: Find the atmospheric true boiling point distillation curve for a heavy gas oil with the following 10 mm ASTM D 1160 distillation:

10 mm ASTM D 1160

Volume Percent Off.....	IBP	10	30	50	70	90
Temperature, °F.....	397	454	496	531	579	640

Solution: The results of the calculations are tabulated below:

Step 1 The 10 mm ASTM D 1160 distillation is tabulated in Columns 1 and 2.

Step 2 Determine the difference between the indicated points on the ASTM D 1160 curve.

Step 3 As stated on Figure 13.3 at 10 mm the TBP 50% is equal to the ASTM D 1160 50% point of 531° F.

Step 4 From the differences found in Step 2, determine the corresponding 10 mm TBP differences from Figure 13.3.

Step 5 Points on the 10 mm TBP curve are obtained by subtracting or adding to the TBP 50% point the differences found in Step 4.

Step 6 Transpose the 10 mm TBP points to TBP at 760 mm by Figure 13.1.

ASTM D 1160 (10 mm)			TBP (10 mm)		TBP (760 mm)
Step 1			Step 2	Step 4	Step 6
Vol. % Off	t, °F	Diff. °F	Diff. °F	t, °F	t, °F
0	397			350	615
		57	89		
10	454			439	724
		42	50		
30	496			489	786
		35	42		
50	531			531*	837
		48	48		
70	579			579	896
		61	61		
90	640			640	971

* At 10 mm, ASTM D 1160 50% = TBP 50% = 531 °F (Step 3).

Example 5: Construct a phase diagram in the vacuum region for a residuum with the following 10 mm TBP distillation:

10 mm True Boiling Point Distillation

Volume Percent Off.....	0	10	30	50	70	90
Temperature, °F.....	178	300	402	507	625	748

Solution: Tabulated results of the calculations and the phase diagram are shown below:

Step 1 The 10 mm TBP distillation is tabulated in Columns 1 and 2.

Step 2 Determine the temperature difference between the indicated points on the TBP curve.

Step 3 From the 10 mm TBP 30-10% temperature difference of 102° F and TBP 50% point of 507° F the 10 mm EFV 50% point is found from Figure 13.4 to be 492° F.

Step 4 From the temperature differences found in Step 2, determine the corresponding 10 mm EFV temperature differences from Figure 13.5.

Step 5 To the 10 mm EFV 50% point add and subtract the differences found in Step 4 to obtain the 10 mm EFV curve.

Step 6 Transpose the 10 mm EFV 50% to 760 mm EFV 50% by use of Figure 13.8. Since the EFV temperature differences are constant in the vacuum region, the 760 mm EFV curve is obtained by subtracting or adding the differences found in Step 4 to the 760 mm EFV 50% point.

Step 7 The phase diagram shown in Figure 13.9 is constructed by locating the temperatures determined for the various EFV percentages vaporized at 10 mm and 760 mm on a log P vs 1/T plot and drawing straight lines between corresponding percent vaporized points.

Consistency Between Atmospheric and Vacuum EFV Correlations. The three-way correlation relating the atmospheric ASTM, TBP, and EFV, shown as Figures 12.4 through 12.9, are applicable to petroleum fractions with normal boiling points up to 800° F. For heavier stocks, similar relationships for the 10 mm ASTM D 1160, TBP, and EFV, shown as Figures 13.3 through 13.7, are applicable. Figure 13.8 relates the EFV 30% and 50% temperatures at various subatmospheric pressures, while the TBP and the ASTM curves at 10 and 760 mm Hg are related by Figures 13.1 and 13.2.

TBP (10 mm)			EFV (10 mm)		EFV (760 mm)
Step 1		Step 2	Step 4	Step 5	Step 6
Vol. % Off	t, °F	Diff. °F	Diff. °F	t, °F	t, °F
0	178			287	577
		122	48		
10	300			335	635
		102	77		
30	402			412	702
		105	80		
50	507			492[1]	782[2]
		118	92		
70	625			584	874
		123	97		
90	748			681	971

[1] 10 mm EFV 50% obtained from Figure 13.4 (Step 3).
[2] 760 mm EFV 50% obtained from Figure 13.8.

Figure 12.1 illustrates the interrelationships. There are nine correlations which are consistent and should not be extrapolated. The atmospheric three-way correlations and the 10 mm Hg three-way correlations overlap each other by about 125° F. In this region these two sets of correlations are consistent. Thus, for stocks which fall in this overlap region, either the atmospheric or 10 mm Hg correlations may be used to predict the EFV curve.

Plant data on vacuum flashing residua have been published[14] with laboratory data on the reduced crude charges. An attempt was made to evaluate these correlations with the data. The results are inconclusive, however, because of uncertainties about the laboratory distillation data and the corrected flash zone pressure.

Assuming that the laboratory distillation is a TBP and that Figures 13.4 and 13.5 apply and that the pressures given were corrected rather than actual pressures, the calculation method gave volume percent flashed results that were an average of 8% high, varying from 2% to 13% high. This indicated that the correlations given here predict vacuum flash zone temperatures that are from 10° F to 60° F low. This is significant and requires further checking.

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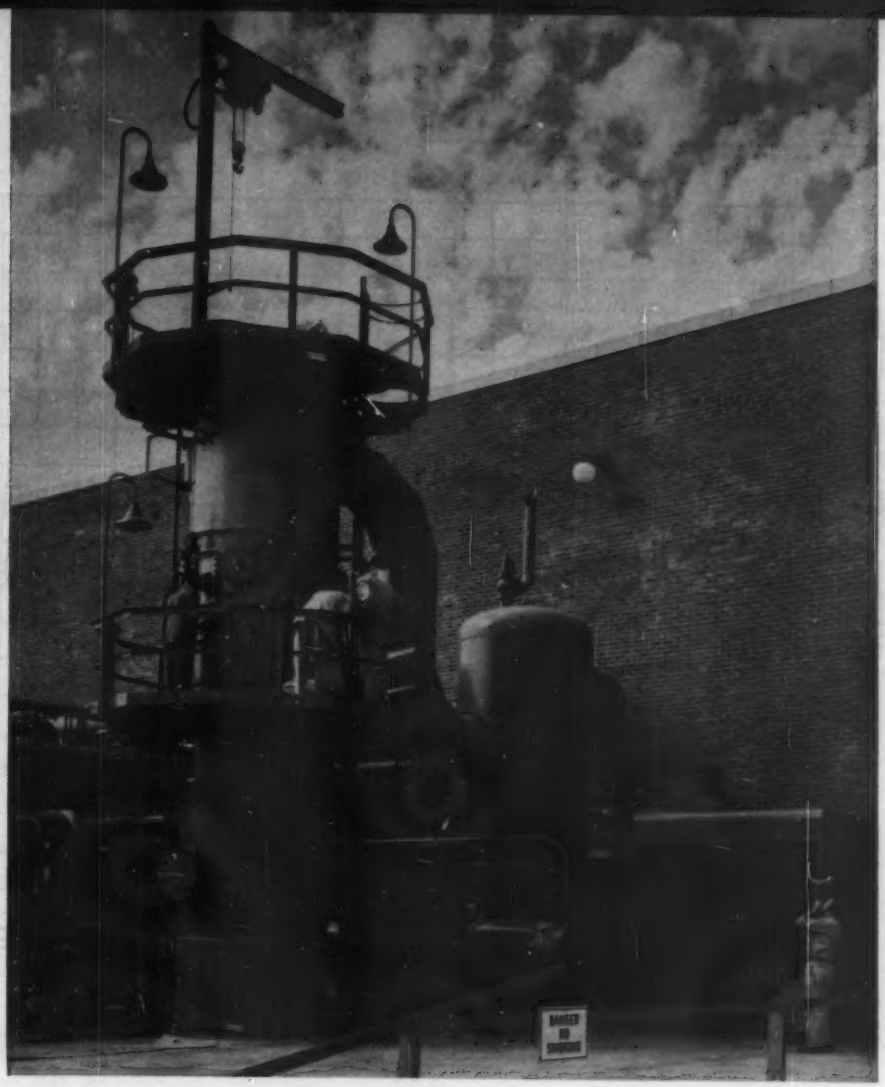

FIGURE 1—Air-water tests were made in a 66-inch column to check the effect of tray levelness on performance.

Are Level Trays Worth Their Cost?

What happens when fractionation trays are not level? Here are test data on sieve trays along with some typical costs to help you decide

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THE SPECIFICATIONS of some companies call for close tolerances on tray levelness in fractionating columns. Recent tests indicate, however, that trays need not be level for good operation, and careful estimates show that close tolerances on tray levelness add significantly to column cost.

To check out the effect of tray levelness on performance, air-water tests were made in the 66-inch diameter column using sieve trays with overflow weirs and downcomers. The test column is shown in Figure 1.

The sieve trays in the column were tilted so that the outlet weir side of the tray was ½-inch above the inlet side. This direction of tilt gives the most severe test because any hydraulic gradient increases the effect of the tilt. In these tests, weepage was used to measure the effect of tray levelness on performance. The reasons are as follows.

At higher vapor loads, the entire bubbling area of a tray is active,

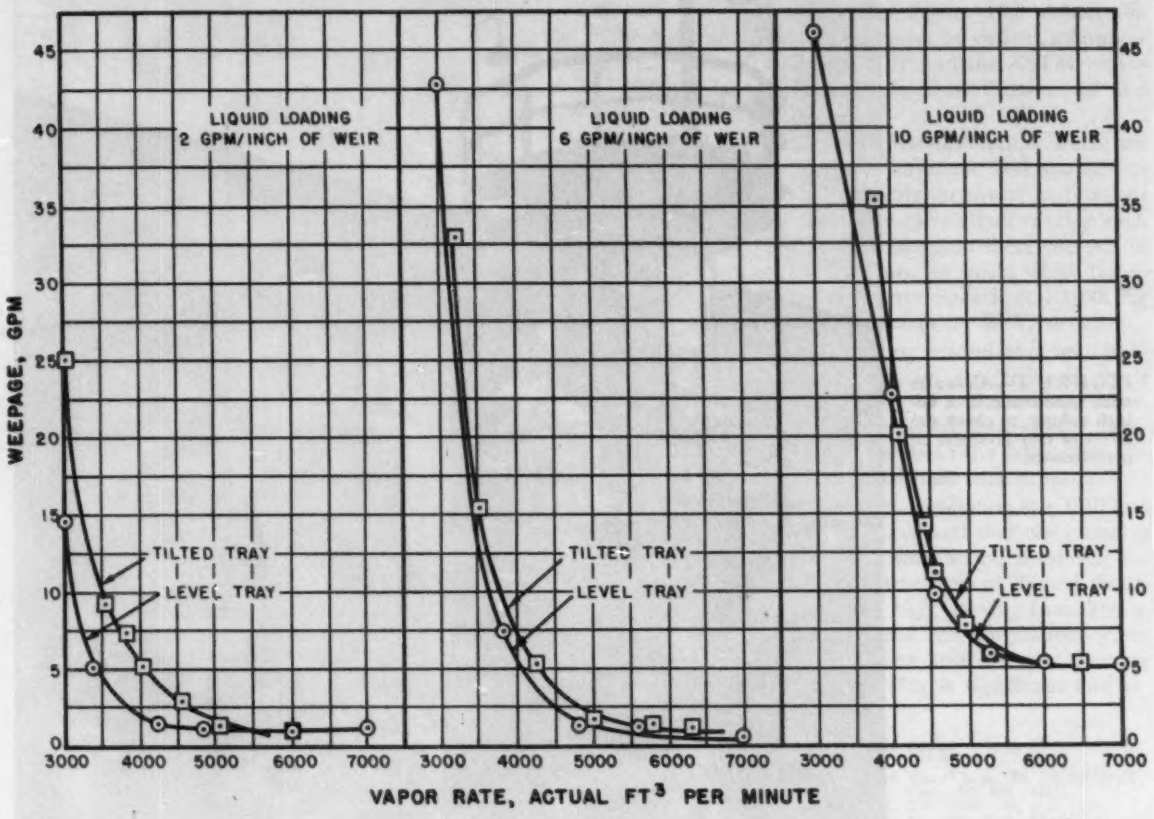

FIGURE 2—The weepage quantity reaches about the same constant minimum for both the tilted and untilted trays.

producing a uniform foam. The foam height is such that an out-of-levelness such as ½-inch is a small fraction of the total foam height, and thus could not produce a significant variation in vapor load across the tray. But even if there were a significant variation, it would not have much effect on performance. Several investigators[1, 2, 3] have shown for bubbletrays that, at higher vapor rates, efficiency is relatively independent of vapor load, until appreciable entrainment occurs. This is also true for a properly designed sieve tray.[4, 5]

Other investigators[6] have shown that tray levelness has little effect on the vapor velocity at which the entire bubbling area becomes active. This leaves weepage as the principal factor influencing performance that can be affected by tray levelness.

Thus, weepage tests were conducted for six column conditions—three for tilted trays and three for untilted trays. The results are shown in Figure 2. The curves give the total quantity of liquid weeping through a tray as a function of vapor rate. Only the low vapor-rate part of the operating curve is shown.

There are two significant facts shown by these data: *First, the weepage quantity reaches about the same constant minimum for both the tilted and untilted trays. And secondly, the vapor rate at which the weepage reaches the constant minimum is essentially the same for both trays at normal liquid loadings.* Even at the low liquid loading of two gallons per minute per inch of weir, the vapor rate at which weepage reaches this constant minimum is not significantly different for the two trays. Thus, ½-inch out-of-levelness does not materially affect tray performance.

As a matter of interest, tests were run on sieve trays with various hole sizes and percentage open area. The characteristic shape of the weepage curve is the same for all these various designs, but the location of the curve changes with the design. Out-of-levelness tests were also run on representative bubblecap trays. The results were similar. The sieve-tray tests are reported here because sieve trays are more sensitive to levelness at low vapor loads.

Very low liquid loadings occasionally dictate the design of a column—say loads under one gallon per minute per inch of weir length. Tray levelness becomes important at low liquid loadings, because any weepage can represent a relatively large percentage of the total liquid flow. But this requirement exists in less than 10 percent of the columns

in a typical refinery or chemical plant. For the great majority of columns, tight tray levelness is not required.

How much does tray levelness cost? To answer this question, comparative costs were estimated for trays installed at three different level tolerances. These estimates were made for both shop-installed, welded-in type trays and for field-installed sectional-trays.

First, to the welded-in trays. Two columns were considered, each for two pressures—a 72-inch column with 30 trays, and a 120-inch column with 30 trays. For the 72-inch column, taking ¼-inch as a normal out-of-level specification, the added cost was computed for a 1/16-inch tighter level specification, and for a ⅛-inch tighter level specification. For the 120-inch column, taking ⅜-inch as a normal out-of-level specification, the added cost was estimated for a 1/16-inch tighter level specification and for a ⅛-inch tighter specification.

For both columns, the 1/16-inch tighter specification increased column cost about 3 percent on a column rated for a pressure of 100 psi, and about 2 percent on a column rated for a pressure of 600 psi. For the ⅛-inch tighter levelness, the cost increases about 4 percent in the 100 psi column, and about 3 percent in the 600 psi column. The actual dollar value of the columns used in this example vary from $25,000 to $75,000. Thus, the added cost of tray levelness amounts to $1,000 to $2,000.

The cost of tray levelness for segmental trays installed in the field varies widely. Factors that affect the cost are size of column, tray spacing, and climatic conditions. But assuming average conditions, the added cost of leveling the trays, after they have been installed, is about the same as the added cost for welded-in trays.

Other factors can later throw a column out of level even though trays are originally installed perfectly level. These factors include installation of the column on its foundations, the effect of high winds, and the effect of sun.

The general practice for setting a column on its foundation is to check its plumbness in two directions, 90 degrees apart, using a transit. This method tells if a column is plumb within an inch or two. Closer alignment is of little value because the bow of the column shell from manufacturing tolerances can be greater than an inch in a 100-foot column. One inch in a 100-foot, 72-inch diameter column could throw the top tray off level by about 1/16 inch.

A factor that might at first thought seem important to tray levelness is wind load. To check this out, the out-of-levelness of the top tray of a column 36 inches in diameter by 120 feet tall was computed with several wind loads. For a wind velocity of 25 miles per hour, the top tray goes out of level only 1/64 of an inch. At 50 miles an hour, the out of level due to the wind is 1/16 of an inch. Thus wind load, as such, is not an important factor in tray levelness.

Another factor that can affect tray levelness is sun on an uninsulated column during field installation of the trays. If the morning sun were beating down on one side of the column, it could easily get as much as 25 degrees hotter than the other side. In a 100-foot column, this can tilt the top tray ¼-inch out of level. And trays that are installed as level in the morning, could be ¼-inch out of level at noontime, or when the column is finally insulated.

Summing up. Trays that are out of level by as much as ½-inch do not significantly affect column performance. Close tolerances on tray levelness do increase manufacturing costs. Factors other than tray installation can affect the levelness of a tray. Thus, it seems uneconomic to spend money for tray levelness closer than ¼ to ½ inch in most refinery or chemical plant columns.

This article is an expansion of a presentation made before the Technical Advisory Committee of the Fractionation Research, Inc., Tulsa, June, 1958.

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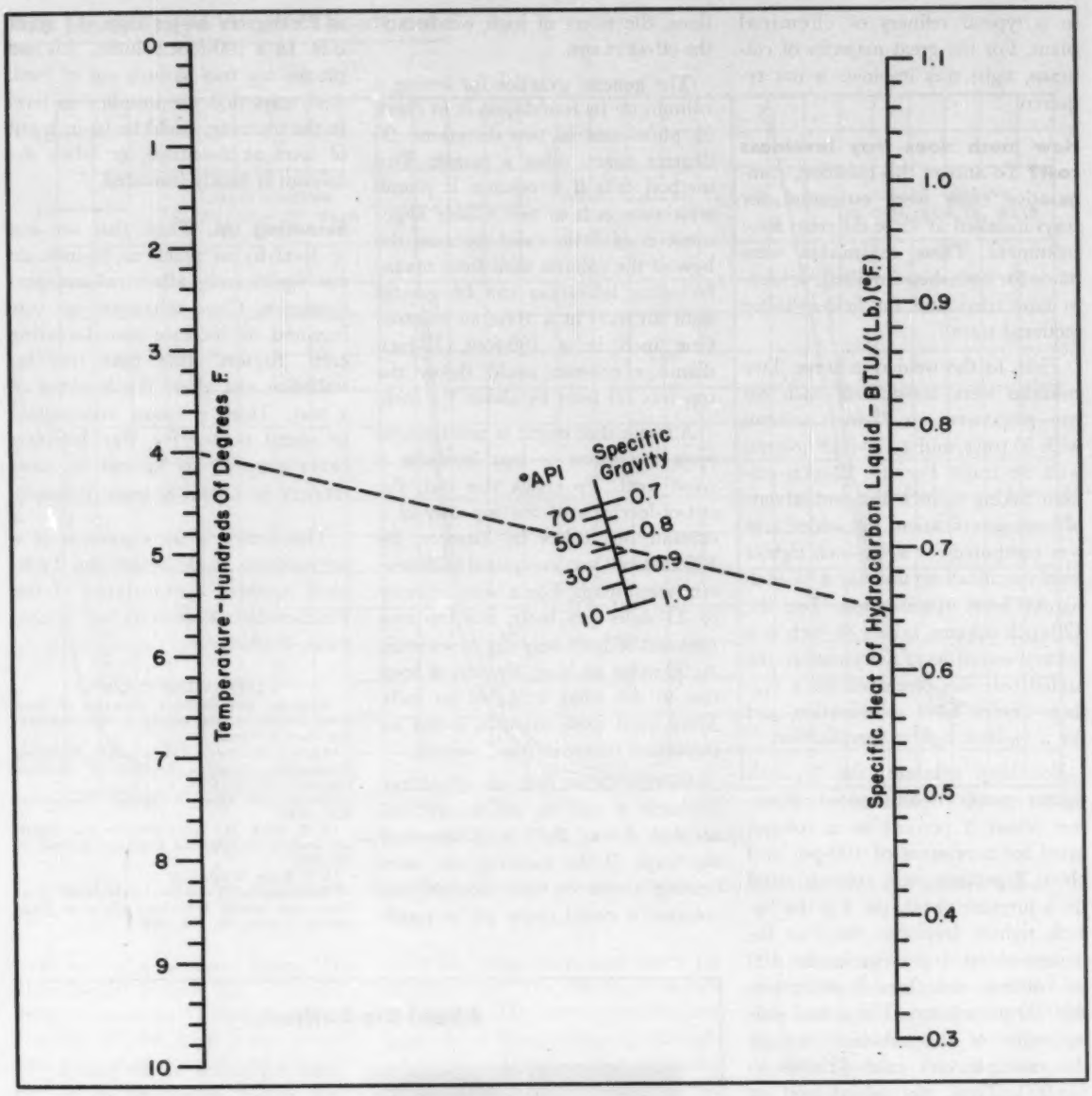

Specific Heats of Hydrocarbon Liquids

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THE ACCOMPANYING line coordinate chart, based on reliable data[1] enables one to find the specific heat of a hydrocarbon liquid at a pressure of one atmosphere when the temperature and the specific gravity (or the number of degrees API) are known.

The broken index line on the chart shows that a hydrocarbon liquid with a specific gravity of 0.825 (40° API) has a specific heat of 0.65 Btu/(lb)(F.) at a temperature of 400 F.

LITERATURE CITED

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Ideal K's for Acetylene

Ideal vaporization equilibrium constants are given for pressures up to 1,000 psia and over a temperature range of —114.9 to 97.4 F

D. S. Hoffman and J. H. Weber*
University of Nebraska, Lincoln

IN THE PRODUCTION of acetylene from light hydrocarbons it is necessary to separate the acetylene from other reaction products and unreacted feed materials. The separation processes involved are usually distillation, absorption, and stripping. To design units for any one of these purposes, a knowledge of the ideal K's for acetylene is useful.

It is the purpose of this paper to present ideal K values for acetylene over the temperature range —114.9 to +97.4 F. and up to pressures of 1,000 psia.

In previous papers[1,2,3] the method of calculations has been discussed in detail. The basic equations are given here and the reader is referred to the earlier articles for the nomenclature, methods, and discussion.

$$\frac{y}{x} = K' = K\frac{\nu}{\phi} \qquad (1)$$

$$RT \ln \frac{f_2}{f_1} = \int_{P_1}^{P_2} V dP \qquad (2)$$

$$\ln \frac{f_v^\circ}{P} = -\frac{1}{RT}\int_o^P \left(\frac{\alpha}{}\right) dP \qquad (3)$$

$$f_1^\circ = f_{P_v} e^{\frac{V^*}{RT}(P - P_v)} \qquad (4)$$

For this work the vapor phase fugacity values were taken from data presented by Weber[6] and the generalized correlation of Lydersen, Greenkorn, and Hougen.[5] Liquid phase fugacities were calculated by Equation (4), molal liquid volume data were obtained from Lange's Handbook.[4]

The consistency of the f_v° data are shown on a semi-logarithmic plot of f_v°/P vs. P and the consistency of the f_1° data, on a semi-log-

TABLE 1—Fugacity and Vaporization Equilibrium Constants for Acetylene

Property	FUGACITY Liquid	FUGACITY Vapor	Vapor Equil. Constant	FUGACITY Liquid	FUGACITY Vapor	Vapor Equil. Constant
Temperature, F		—114.9			—76.9	
Vapor Pressure, psia		17.63			50.0	
Pressure, psia						
14.7	(17.4)*	14.4	1.22	(46.8)	14.5	3.23
25	17.5	(24.0)	0.730	(46.9)	24.3	1.93
50	17.6	(46.0)	0.380	47.0	47.0	1.00
75	17.6	(66.9)	0.260	47.1	(68.6)	0.687
100	17.7	(86.3)	0.205	47.5	(88.5)	0.537
150	17.9	(120)	0.149	47.9	(125)	0.383
200	18.1	(148)	0.122	48.3	(158)	0.306
300	18.4	(191)	0.0964	49.1	(207)	0.237
400	18.7	(218)	0.0858	50.0	(244)	0.205
500	19.1	(236)	0.0809	50.9	(270)	0.189
700	19.8	(256)	0.0774	52.7	(298)	0.177
1000	20.9	(269)	0.0776	55.5	(320)	0.173
Temperature, F		— 45.8			— 9.4	
Vapor Pressure, psia		100.0			200.0	
Pressure, psia						
14.7	(89.4)	14.6	6.12	(169)	14.6	11.55
25	(89.6)	24.5	3.66	(169)	24.5	6.90
50	(90.0)	48.7	1.85	(170)	48.0	3.54
75	(90.3)	69.6	1.30	(170)	70.5	2.42
100	90.7	90.7	1.00	(171)	92.3	1.85
150	91.5	(126)	0.725	(173)	133	1.30
200	92.1	(167)	0.550	174	174	1.00
300	93.8	(222)	0.423	177	(237)	0.747
400	95.1	(271)	0.351	180	(290)	0.620
500	96.5	(305)	0.316	183	(334)	0.548
700	99.6	(344)	0.290	189	(389)	0.486
1000	104	(374)	0.278	199	(419)	0.474
Temperature, F		32			60	
Vapor Pressure, psia		386.6			570.1	
Pressure, psia						
14.7	(280)	14.6	19.2	(380)	14.6	26.0
25	(280)	24.6	11.4	(381)	24.7	15.4
50	(281)	48.5	5.80	(382)	49.4	7.75
75	(282)	71.7	3.93	(384)	72.6	5.29
100	(284)	94.2	3.01	(387)	95.7	4.04
150	(286)	137	2.09	(390)	140	2.78
200	(289)	177	1.64	(393)	182	2.15
300	(294)	246	1.20	(400)	260	1.54
400	298	(308)	0.968	(408)	328	1.24
500	304	(357)	0.853	(415)	387	1.07
700	316	(428)	0.738	430	(470)	0.915
1000	330	(482)	0.685	454	(531)	0.855
Temperature, F		97.4				
Vapor Pressure, psia		905				
Pressure, psia						
14.7	(469)	14.6	32.0			
25	(471)	24.8	19.0			
50	(474)	49.3	9.61			
75	(477)	73.4	6.50			
100	(481)	97.2	4.94			
150	(487)	144	3.39			
200	(494)	188	2.63			
300	(508)	272	1.87			
400	(522)	348	1.50			
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700	(568)	529	1.07			
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* Fugacity values in parentheses are those in the hypothetical states.

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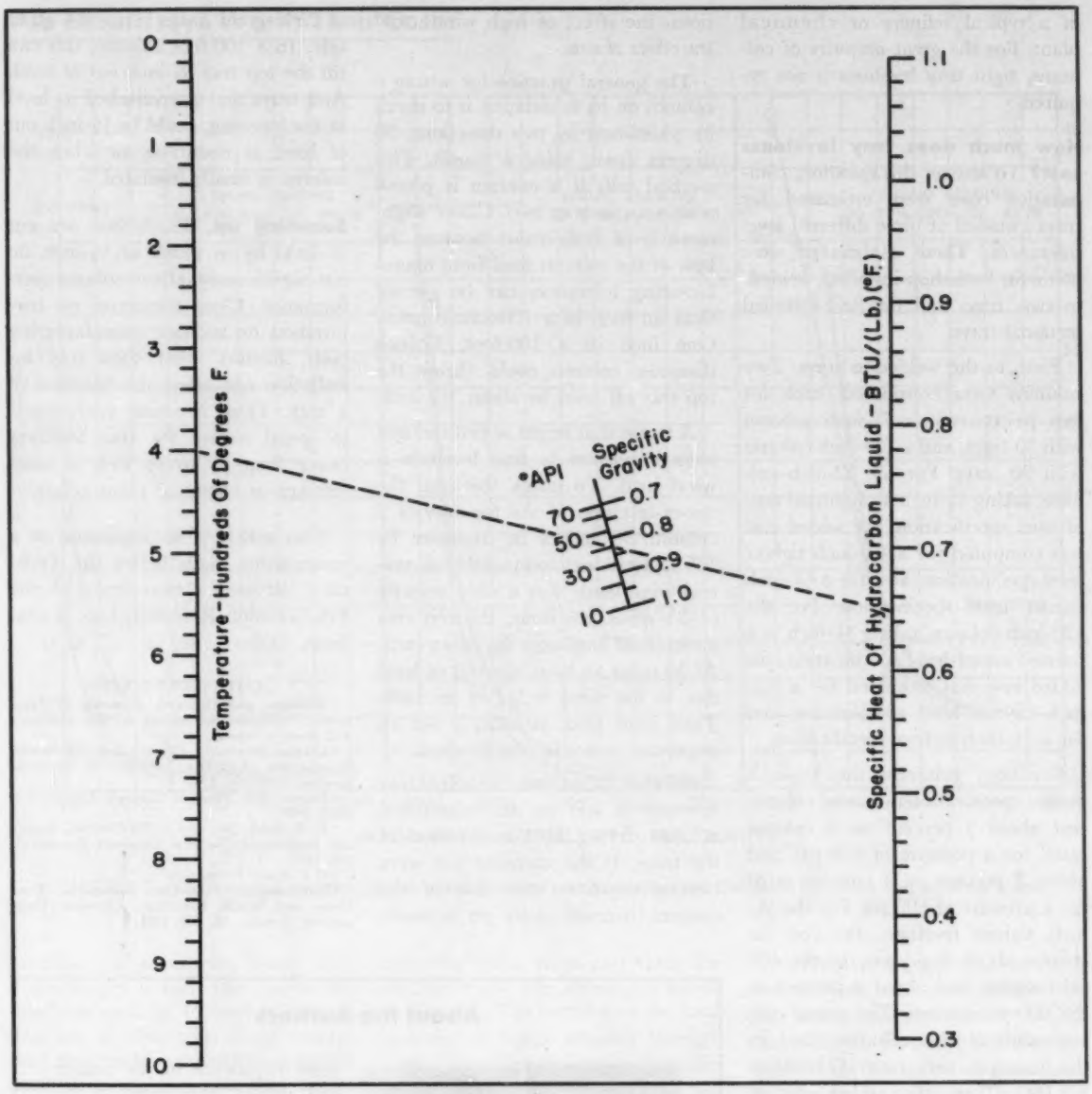

Specific Heats of Hydrocarbon Liquids

D. S. Davis
University of Alabama, University, Ala.

THE ACCOMPANYING line coordinate chart, based on reliable data[1] enables one to find the specific heat of a hydrocarbon liquid at a pressure of one atmosphere when the temperature and the specific gravity (or the number of degrees API) are known.

The broken index line on the chart shows that a hydrocarbon liquid with a specific gravity of 0.825 (40° API) has a specific heat of 0.65 Btu/(lb)(F.) at a temperature of 400 F.

LITERATURE CITED

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Ideal vaporization equilibrium constants are given for pressures up to 1,000 psia and over a temperature range of —114.9 to 97.4 F

D. S. Hoffman and J. H. Weber*
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IN THE PRODUCTION of acetylene from light hydrocarbons it is necessary to separate the acetylene from other reaction products and unreacted feed materials. The separation processes involved are usually distillation, absorption, and stripping. To design units for any one of these purposes, a knowledge of the ideal K's for acetylene is useful.

It is the purpose of this paper to present ideal K values for acetylene over the temperature range —114.9 to +97.4 F. and up to pressures of 1,000 psia.

In previous papers[1,2,3] the method of calculations has been discussed in detail. The basic equations are given here and the reader is referred to the earlier articles for the nomenclature, methods, and discussion.

$$\frac{y}{x} = K' = K\frac{y}{\phi} \qquad (1)$$

$$RT \ln \frac{f_2}{f_1} = \int_{P_1}^{P_2} V dP \qquad (2)$$

$$\ln \frac{f_v^\circ}{P} = -\frac{1}{RT}\int_o^P \alpha \, dP \qquad (3)$$

$$f_l^\circ = f_{P_v} e^{\frac{V^*}{RT}(P - P_v)} \qquad (4)$$

For this work the vapor phase fugacity values were taken from data presented by Weber[6] and the generalized correlation of Lydersen, Greenkorn, and Hougen.[5] Liquid phase fugacities were calculated by Equation (4), molal liquid volume data were obtained from Lange's Handbook.[4]

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Ideal K's for Acetylene . . .

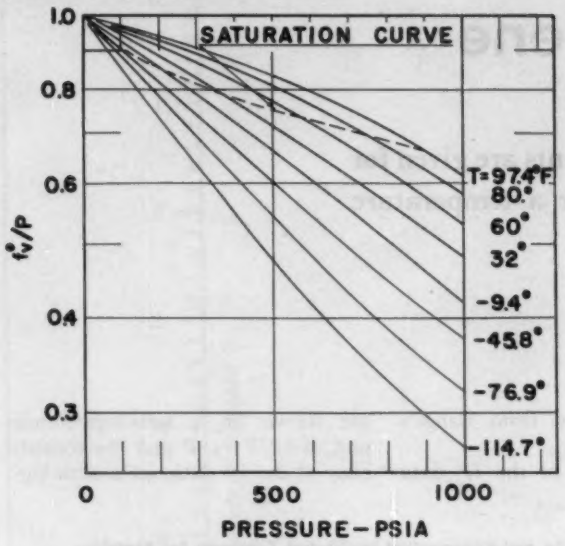


FIGURE 1—Consistency of the $f_v°$ data.

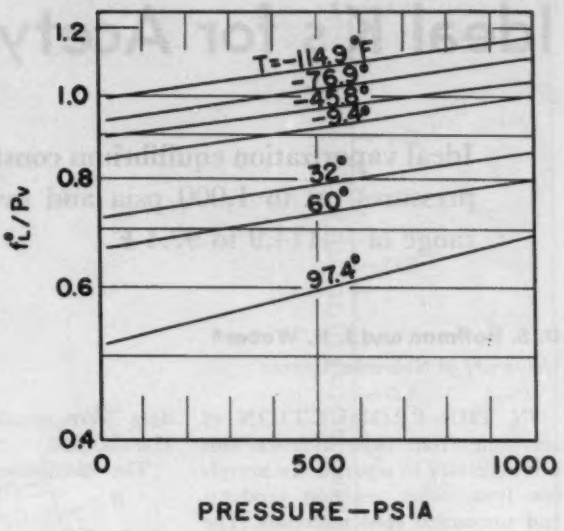
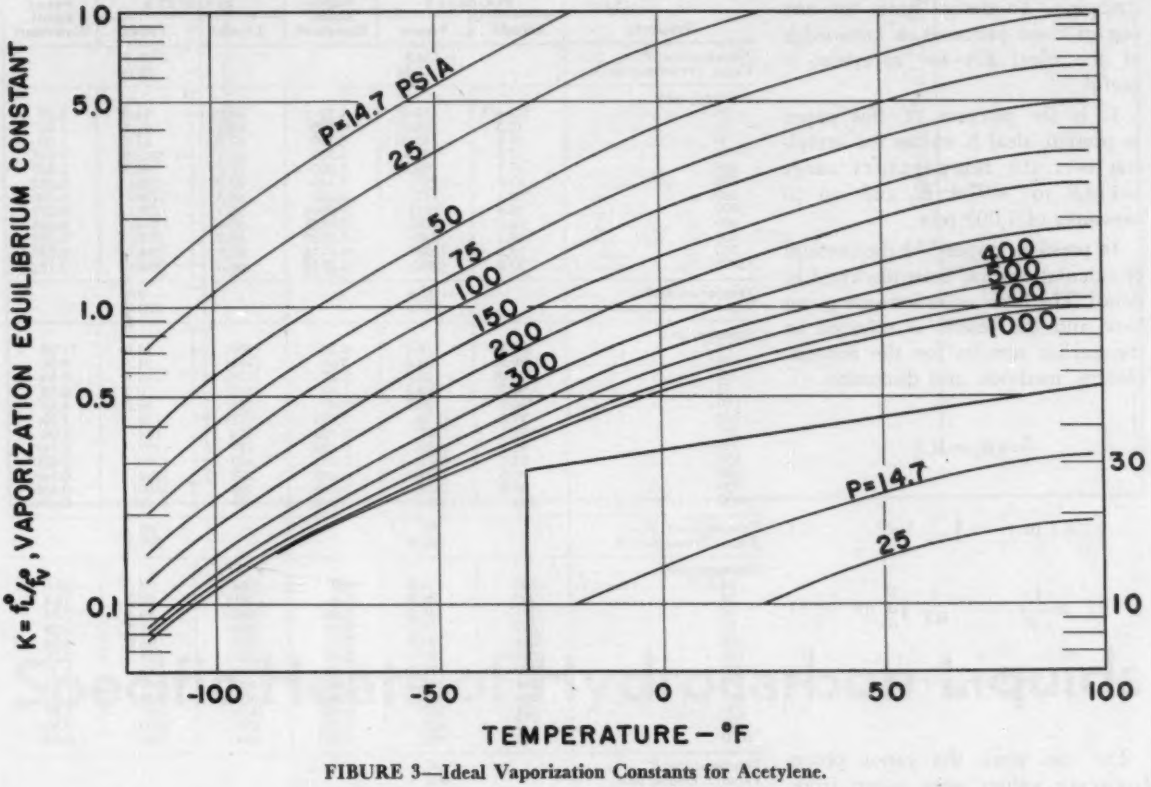


FIGURE 2—Consistency of the $f_1°$ data.



FIBURE 3—Ideal Vaporization Constants for Acetylene.

arithmic plot of $f_1°/P_v$ vs. P, Figures 1 and 2, respectively. From the fugacity data, ideal K data were calculated. The results are shown in tabular form in Table 1 and in graphical form, Figure 3.

No attempt was made to evaluate ideal K's above the critical temperature of acetylene, +97.4 F., because of the uncertainty in the determination of $f_1°$ values at this condition.

ACKNOWLEDGMENT

A portion of the work on properties of acetylene in the paper was done as a part of a consultantship arrangement with Phillips Petroleum Company. The authors thank Phillips for permission to publish the information.

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[1] Hoffman, D. S., and Weber, J. H., PETROLEUM REFINER, 34, No. 2, 137 (1955).

[2] Ibid., 35, No. 3, 213 (1956).

[3] Ibid., 35, No. 10, 163 (1956).

[4] Lange, N. A. (Editor) "Handbook of Chemistry," 8th Edition, Handbook Publishers, Inc., Sandusky, Ohio (1952).

[5] Lydersen, A. L., Greenkorn, R. A., and Hougen, O. A., Rept. No. 4, Engr. Exp. Sta., University of Wisconsin, Madison, Wis.

[6] Weber, J. H., to be published in 1959 in AIChE Journal.

How to Specify Protective Coatings

There are seven points to consider before writing a coating spec and three inspections to be made during and after the application

J. R. Allen and G. Mackey
E. I. du Pont de Nemours and Co., Inc.
Wilmington, Delaware

A GOOD specification has to be a compromise between practicality, cost and performance. An inadequate specification, such as one calling for a good painting system without sufficient surface preparation, is a waste of time and money. Similarly a more than adequate specification, such as blasting to white metal where a brush-off or commercial blast would be satisfactory, results in money spent unjustifiably.

A specification should be realistic, and the requirements should be within the realm of reasonable and practical performance by the applicator with accepted materials, methods, and equipment. To be complete, a specification must cover surface preparation, coating material, and application in detail and with sufficient clarity to avoid misinterpretation. Like a three-legged stool, inadequacy in any one of these renders the entire job essentially ineffective. In addition, a specification must outline and require inspection to insure that the quality of the job falls within defined limits.

Before the preparation of a coating specification for any given job, it is necessary to obtain a certain background of information to outline the requirements and limitations.

Exposure and Service Conditions. (a) Is the exposure indoor or outdoor? (b) If it is an outdoor exposure, geographical location must be established since it can affect severity. For example, extremely hot or cold climates as well as seacoast locations can affect the choice of coating. (c) Is there exposure to chemicals and, if so, determine kind, concentration, and temperature as well as whether the exposure is immersion, splash and spill, or fumes. (d) What is the service temperature range of the substrate, and is it continuous or cyclic? If cyclic, what is the frequency? (e) Are other special conditions such as abrasion, abuse, flexing, vibration, or impact involved?

Substrate Material and Condition. (a) The kind of substrate must be known, such as carbon steel, galvanized steel, nonferrous metals, masonry, and wood. (b) With previously uncoated substrates encountered in new construction, the degree of weathering in regard to mill scale and rusting must be known. (c) With previously coated substrates encountered in maintenance work, the degree and type of deterioration of original coating and substrate must be known as well as the type of original coating and kind and extent of chemical contamination involved, if any.

Local Limitations. (a) Does potential contamination of product or equipment limit the cleaning or application methods that may be used? (b) Is there potential contamination of surfaces between cleaning, priming, and subsequent coats? (c) Are there any time limitations for completion of the work? (d) Are there any unusual climatic conditions expected, such as extremes of temperature, humidity, or rain that must be considered? (e) Are there any special considerations that should be given to labor relations? (f) In addition to normal good safety practices, are any special considerations required due to local conditions? For example, do they eliminate the use of spark producing cleaning methods or require unusual ventilation?

Size, Shape, Complexity, and Accessibility. (a) If tanks are involved, are they on the ground or elevated and is the interior, exterior, or both to be coated? (b) In the case of structural steel, are small and complicated elements involved? Also, is accessibility difficult due to congestion or over-all height? (c) In the case of piping, the same considerations apply as for structural steel. (d) Is the equipment of unusual shape or complexity and is accessibility limited or difficult? (e) Are there any unusual heights or depths involved in connection with walls, ceilings, or floors? Are there any other unusual architectural features or complexities that require special consideration?

Color Limitations. Is a wide choice of color permissible, is it limited to

a narrow range, or is there no choice, a specific color being required?

Economics: Cost vs. Performance. As the first step in determining or analyzing the economics of any coating system, it is necessary to establish its objective. For example, is the primary function protection, decoration, elimination of product contamination, or a combination of these? Having established the objective, the economic goal then is to select, based on established performance data, the coating system that accomplishes the objective at the lowest cost per square foot per year, the only true cost index of a coating.

These seven factors are considered individually as questions and answers are established as dictated by the specific coating problem. This process provides the basic data for a coating specification. Of course, the degree of analysis made is dependent on the magnitude of the job.

Writing A Specification. There are two general systems for the writing of a job specification. One includes all the necessary details to make it self-sufficient without the need of any reference standards. The other system uses a brief job specification supported by references to Standard Coating Specifications. Du Pont uses the latter system. The following is a typical job specification for painting new structural steel exposed to mild HCl fumes outdoors.

Surface Preparation	II
Coating System	53
Application Method	HS

This job specification is supported by Standard Engineering Specifications from which we find that a Class II surface preparation requires commercial sandblasting for which the necessary materials, equipment, and techniques are outlined. The Standard Engineering Specification also shows that coating system No. 53 is a protective system consisting of 3 mils dry film thickness each of a primer and a finish coat which are named and described. It should be noted that we specify coating materials by trade names and by formulation. This job specification calls for application by hot spray, also for which the equipment and techniques are outlined. In some cases, particularly in decorative painting, the application method is not specified, leaving it optional. Our Standards cover in detail all pertinent aspects of protective and decorative painting. Since they consist of over 100 pages, only a brief outline of their contents can be presented here as follows:

- **Surface Preparation.** (a) Materials, (b) Equipment, (c) Techniques, (d) Definitions of surface conditions before and after cleaning.
- **Coating Systems.** (a) Materials by trade names, (b) Selection, (c) Film Thicknesses.
- **Description of Materials.**
- **Application.** (a) Environmental Limitations, (b) Methods, (c) Equipment.
- **Inspection.** (a) Requirement, (b) Equipment, (c) Techniques.
- **Safety Precautions.**

When there is a large volume of specification work, we have found that the system of use of brief job specifications, supported by detailed standard specifications, saves substantial time and money compared to the system of using detailed job specifications that are self-sufficient.

It must be emphasized that a specification is not adequate unless provision is made to check the work to verify that it meets the specification. Such inspection must cover (1) surface preparation, (2) a periodic check during application, and (3) the completed job. Typical procedures that we use to cover each of these points are:

- **Surface Preparation.** (a) Visual inspection for method is specified, degree of cleanliness and freedom from foreign matter, such as dirt, grease, oil and water with emphasis on "hard to get at" areas. (b) A check of profile on blast cleaned metal surfaces when specified by comparison with reference standards.
- **Periodic Check During Application.** (a) Verification that specified materials are used and in the specified manner. (b) Visual check of each coat for adequate and acceptable workmanship. (c) Spot checks of each coat for wet film thickness, having previously established the ratio of wet to dry film thickness, to insure that the specified dry film thickness is obtained. (d) Visual check for freedom of contamination between coats. (e) Verify that drying time limitations are met. (f) Verify that surface is primed when prescribed. (g) Verify that painting is not done during adverse weather conditions, such as extreme temperatures and humidities.
- **The Completed Job.** (a) Visual check of over-all workmanship. (b) Measurement of total dry film thickness. (c) When specified, check for coating defects using a pinhole detector.

To reap the benefit of good specifications, it has been necessary to "sell," indoctrinate, and train painters, their supervision, and inspectors both within our company and with contractors and equipment manufacturers. Likewise, it has been necessary to establish history record systems covering protective coatings work to measure performance and accomplishment. These records provide information in terms of cents per square foot per year as affected by the surface preparation, application method and coating system used. This provides a continuous record which serves as a guide to direct our efforts toward further improvements in this field.

Great strides have been made but some of the more difficult problems lie ahead. For example, a simple nondestructive method is needed to measure accurately dry film thickness over corners, irregular surfaces, mill scale bearing steel and nonmagnetic materials. Also where blast cleaning is not feasible, a practical and economical means is needed to obtain equivalent surface preparation.

Originally presented before the ASME Maintenance and Plant Engineering conference, Chicago, May 4, 1959. ##

These Factors Affect Exchanger Costs

- TYPE OF CONSTRUCTION
- DESIGN PRESSURE
- TUBE LAYOUT

Here's how your specifications of these variables can affect the ultimate cost of process heat exchangers

R. H. Densmore
Yuba Consolidated Industries, Inc.
San Francisco

THESE VARIABLES—type of construction, tube layout and design pressure—are but three of the many which affect exchanger costs. Others are tube diameter, tube length, materials, specifications requirements, and variations in process design requirements.

Since many of these factors affecting heat exchanger costs are placed into the specifications by the customer's design engineers, and most of the design data is well established, what then can the exchanger manufacturer do to reduce costs without sacrificing quality and still produce a competitive heat exchanger?

Actually, there are several areas affecting final costs in which the manufacturer has positive control. He can control certain mechanical design aspects of the heat exchanger; he can improve shop fabricating techniques and procedures; and he can control the amount of fair profit he hopes to realize on each heat exchanger.

The following discussion concerns those design areas in which the manufacturer can strive to reduce the ultimate cost of heat exchangers.

Types of Construction. Figure 1 shows four types of construction commonly used in process-type heat exchangers. These four types are splitring floating head (SRFH), pull-thru floating head (PTFH) fixed

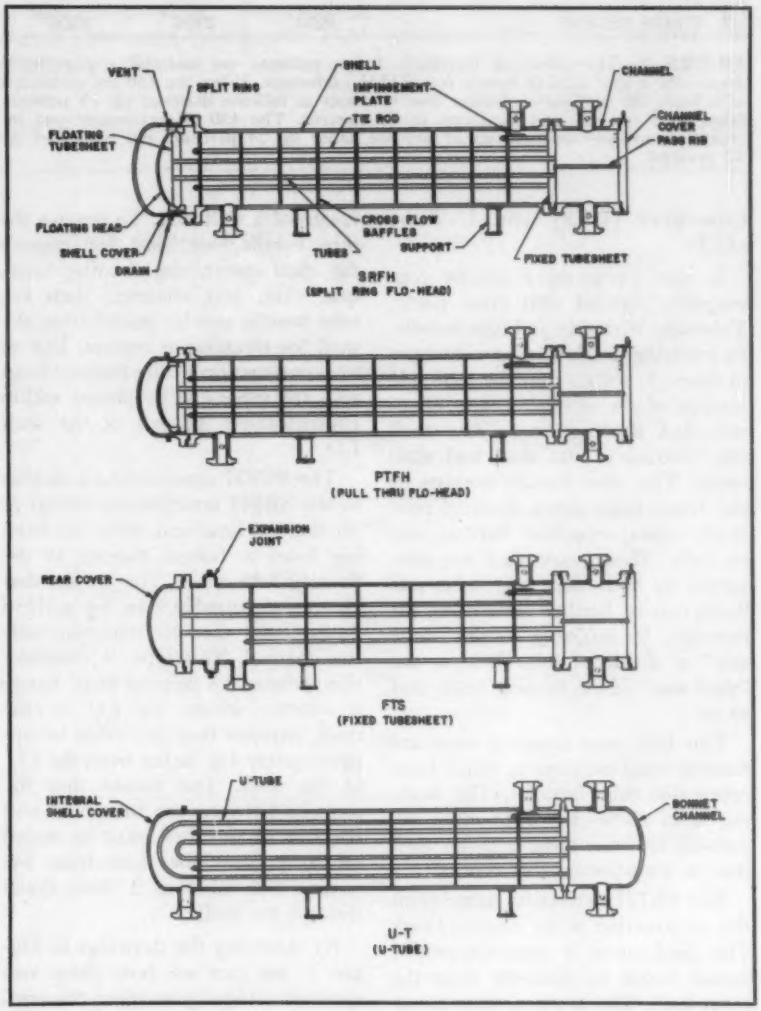


FIGURE 1—Four types of construction commonly used for TEMA Class "R" heat exchangers.

These Factors Affect Exchanger Costs . . .

COMPONENT	MATERIAL		
	150 PSI	300 PSI	450 PSI
1. CHANNEL COVER	3"	3 1/2"	4 1/4"
2. CHANNEL	9/16"	1"	1 3/8"
3. SHELL	7/16"	5/8"	7/8"
4. SHELL SUPPORTS		NO CHANGE	
5. SHELL COVER	7/16"	5/8"	7/8"
6. BODY FLANGES	905#	1280#	2200#
7. FLOHEAD FLANGES	2 7/8"	3 3/4"	4 1/4"
8. FLOHEAD	3/4"	7/8"	1 1/8"
9. NOZZLES	150# ASA	300# ASA	300# ASA
10. TUBESHEETS	2 1/4"	3"	3 3/4"
11. BAFFLES		NO CHANGE	
12. TIE RODS		NO CHANGE	
13. TUBES		NO CHANGE	
14. STUDS	3/4" ϕ	3/4" ϕ	1" ϕ
15. GASKETS		NO CHANGE	
16. WELD ROD	110#	200#	250#
17. STRESS RELIEVE	1500#	2300#	9800#

FIGURE 2—The effect of increased design pressure on material requirements. Basis—36" x 192" x 2,810 square feet PTFH exchanger. Using the 150 psi exchanger as a basis, the 300 psi exchanger cost increases as follows: material up 15 percent, labor up 9 percent, and total cost up 13 percent. The 450 psi exchanger cost increases as follows: material up 37 percent, labor up 24 percent, and total cost up 32 percent.

tubesheet (FTS) and U-Tube (U-T).

A heat exchanger can be conveniently divided into three parts: Tube side, shell side and tube bundle. By referring to the floating-heat types in figure 1, we see that the tube side consists of the channel cover, channels and floating head. The shell side consists of the shell and shell cover. The tube bundle consists of the fixed tube sheet, floating tube sheet, tubes, crossflow baffles, and tie rods. Those parts that are contacted by both shell and tube side fluids can be further referenced, for example, by referring to the "tube side" of the fixed tube sheet or the "shell side" of the floating head, and so on.

The first two types shown are floating head exchangers which have removable tube bundles. The floating head allows for differential expansion between tubes and the shell due to temperature differences.

The SRFH derives its name from the construction at the floating head. The shell cover is approximately 4 inches larger in diameter than the main shell. This is required to house the floating-head flange which is attached to the floating tube sheet by means of a spilt ring. To remove the tube bundle, one must first remove the shell cover, the floating head, split ring, and channel; then the tube bundle can be pulled from the shell for cleaning or repairs. Due to the construction at the floating head end, the tubes can be placed within approximately ¾-inch of the shell I.D.

The PTFH construction is similar to the SRFH construction except at the floating head end. Here the floating head is bolted directly to the floating tube sheet. This means that the tube bundle can be pulled through the shell by removing only the channel. This type of construction, where the floating head flange is entirely within the I.D. of the shell, requires that the tubes be approximately 1⅜ inches from the I.D. of the shell. This means that the annulus between the tube field and the I.D. of the shell must be sealed off to prevent the fluid from bypassing the tubes as it flows down through the shell.

By observing the drawings in Figure 1, we can see how these two types of construction affect the cost. For the same amount of heat transfer surface, the PTFH is generally 2 inches larger in diameter than the SRFH due to the construction at the floating head end. However, the split ring has been eliminated; and all five of the main forged hub-body flanges are identical, which lowers the cost of these flanges. The SRFH unit has three identical flanges at the channel end and two different types at the shell cover end. These factors have the greatest influence on the cost when comparing these two types of construction. We will find later that the cost for these two types of construction are quite comparable.

The fixed tube-sheet type construction is generally used when the shell side fluid is clean and non-fouling. This tube bundle is not removable for maintenance. The differential expansion between tubes and shell is compensated for by an expansion joint in the shell. If the actual operating temperature differences are of a low enough magnitude that an expansion joint is not required, then, of course, the total cost will be lower than shown in Figure 4. The type shown in Figure 1 is the type where the tube sheets form a flange and the channel and rear cover are bolted directly to it. In this type of construction the floating head and two forged hub body flanges have been eliminated, which contribute to its lower cost.

The "U" tube type construction is generally used when the fluid inside the tubes is clean and non-fouling. For this reason, the tube bundle does not have to be too accessible for maintenance so that a bonnet-type channel is standard construction. It is also a popular design for high tube side design pressures and when an internal gasketed joint, which is present in a floating head unit, is undesirable. In this type we have eliminated the floating head, the shell cover flanges, the channel cover, and the channel to channel cover flange. These factors lower the cost but the tubing is not the 16-foot or 20-foot standard lengths generally stocked by manufacturers. Usually, the quantities involved are considerably less than carload so that the cost of the tubing, plus the extras for long tube lengths, is much higher than tubing of standard lengths. The

saving made by eliminating the floating head is practically offset by the cost of bending the tubes. If carload quantities of these special-length tubes are required, the prices shown in Figure 4 can be lowered approximately 10 percent.

The construction details shown in Figure 1 are the basis of the price curves shown in Figure 4. It must be realized, however, that certain design features can be changed which would lower the cost and still meet the requirements of the ASME Code.

Design Pressure. Figure 2 shows the effect of increased design pressure on the major components that make up a heat exchanger. It also shows, using the 150 psi exchanger as a basis, how the material, labor, and total cost increases for the 300 psi and 450 psi units. The unit selected for this comparison is large in diameter so that the full effect of design pressure can be seen. This effect decreases as exchanger size decreases and increases if the exchanger being considered is larger than the 36-inch example used for this comparison.

Tube Layout. Figure 3 shows the effective tube area in square feet versus shell I.D. Tubes are ¾-inch O.D. x 16-feet 0-inch long with two tube passes on the tube side. We have shown drawings of the two tube layouts being considered, 15/16-inch-30° triangular layout and 1-inch 45° rotated square layout. These are the most common tube arrangements for ¾-inch O.D. tubes. The triangular layout is used when the shell side fluid is clean and nonfouling. The square layout is used when this fluid has a tendency to foul and is arranged so that ¼-inch continuous cleaning lanes extend through the entire tube handle. This facilitates cleaning by mechanical means or any other method that may be employed.

This nomograph shows the amount of heat transfer area for the two tube layouts and four types of construction under consideration. It allows you to compare the amount of surface available in a given shell I.D. for these conditions. We can also see the effect of triangular versus square layout on shell diameter. For example, if we select 2100 square feet as a basis, we find that the "triangular" SRFH unit is 29-inches I.D. and that the "square" SRFH unit must be 33-inches I.D. The larger shell diameter required by square layout is the main contributing factor to its higher cost.

Heat Exchanger Costs. The heat exchanger costs shown in Figure 4 are based on the requirements of the ASME Code and TEMA class "R" standards. They are of all steel construction and have ¾-inch O.D., 16 feet 0 inches long tubes with two tube passes through the tubes and

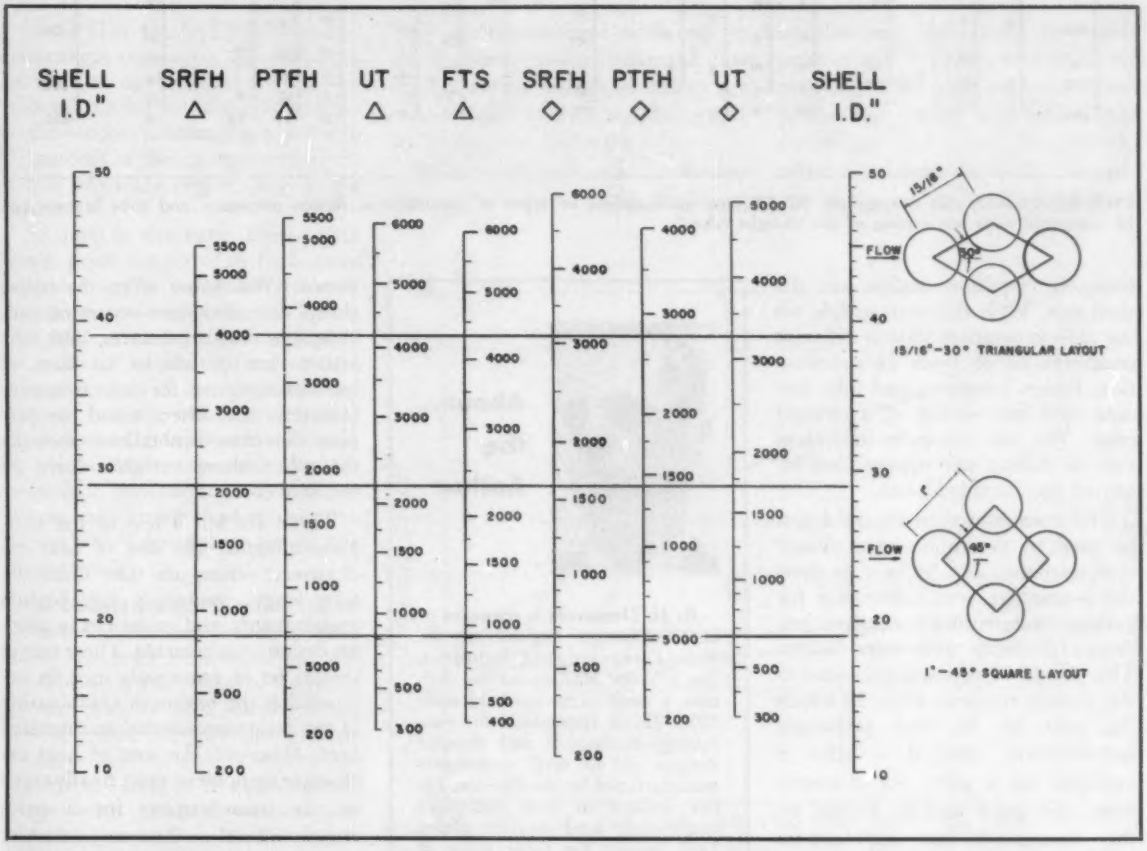


FIGURE 3—The effective tube area in square feet versus shell I.D. for two different tube layouts based on ¾" O.D. x 16' 0" long tubes, two tube passes.

These Factors Affect Exchanger Costs . . .

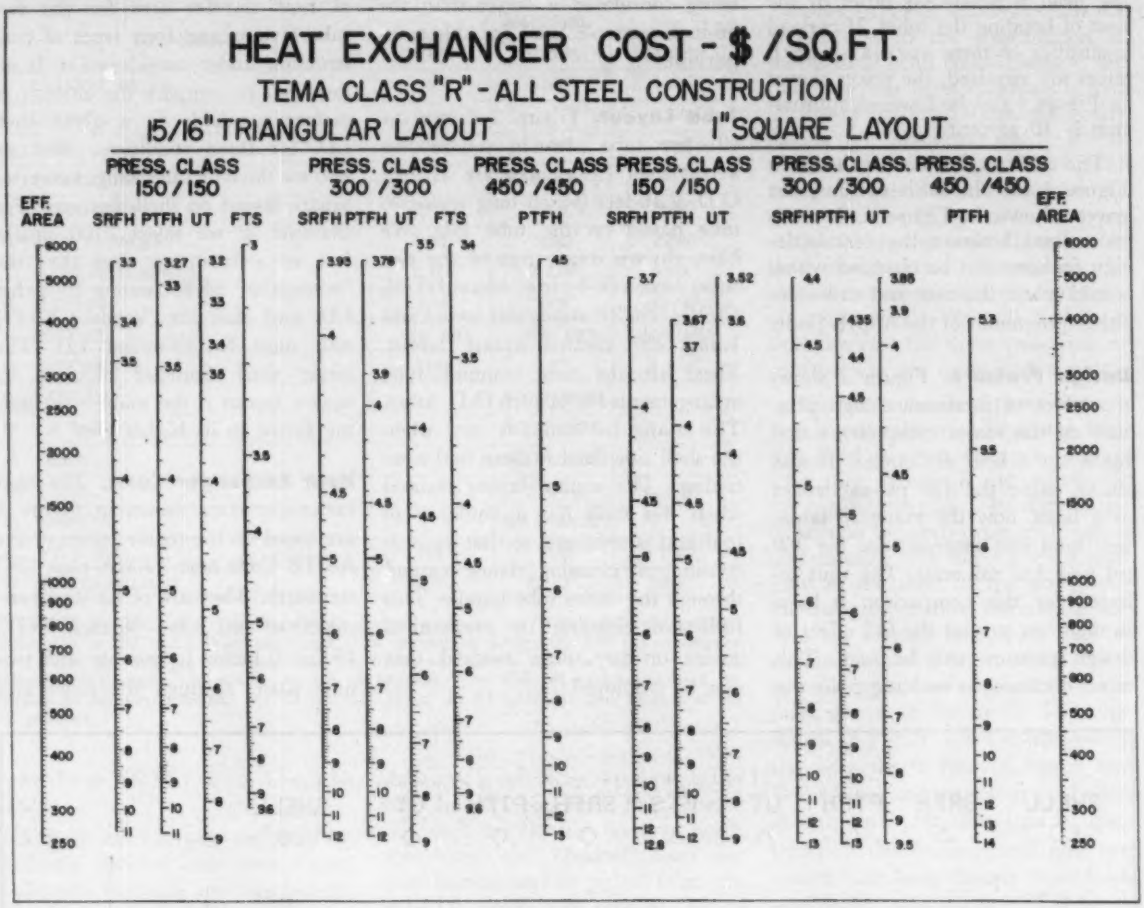


FIGURE 4—With this nomograph, 16 different combinations of types of construction, design pressures, and tube layouts can be compared with one setting of the straight edge.

fourteen cross-flow baffles on the shell side. With this nomograph, we are able to compare sixteen different combinations of types of construction, design pressures, and tube layouts with one setting of a straight edge. We can compare individual cost in dollars per square foot for any of these combinations.

The costs shown in Figure 4 can be used to determine approximate cost; and they can be used to show the percentage cost differential for various combinations of construction, design pressure, and tube layout. This should be of some assistance to the process engineer when he selects the basis for his heat exchanger specifications. Also, if a price is available for a given set of conditions, this point may be plotted on the nomograph and approximate prices read off for other combinations of the variables already mentioned. We know that the three things discussed here—types of construction, design pressures, and tube layout—are of interest to users of heat exchangers; for we, as manufacturers, are often asked to prepare alternate quotations showing the effect these variables have on the final cost.

These are but a few of the variables affecting the cost of heat exchangers; others are tube diameter, tube length, materials, specification requirements, and variations in process design requirements. These curves should be of some assistance in determining the optimum combination of the design considerations discussed here. However, the user of heat exchanger equipment must finally come to the manufacturer for a price which will reflect the many variables in design details and present market conditions. ##

About the Author

R. H. Densmore is manager of heat exchanger engineering for Yuba Consolidated Industries, Inc.'s Yuba Manufacturing division, a position he has held since 1955. He is responsible for estimating mechanical and thermal designs of all heat exchangers manufactured by the division. He has worked in heat exchanger engineering and design since 1942, except for three years of military service.

A Look Behind Natural Gas Prices

Gas prices have gone up rapidly in the past 20 years; here's what to expect in the next 10

E. D. Redding
Wyatt C. Hedrick Engineering Corporation, Houston

DESPITE QUESTIONS about natural gas regulation, gas prices are on the way up. Demand is high now and will be higher in the future. In world economy, natural gas provides 12 percent of the energy consumed; it will provide a bigger share in the future.

As late as the early 1940s, Gulf Coast price ranges of 3 to 5 cents per Mcf at the well-head generally prevailed, some even lower. Today, this price range has been multiplied by a factor of about four to five. The gas prices of the future are uncertain, but the trends and limitations seem to be fairly well indicated. If allowances are made for the hazards in generalizing and predicting on such an involved subject, the factors which shape these trends, can be analyzed.

Coal Looms Large. Considering all factors, for the next decade and beyond, the price of natural gas will be influenced and probably regulated by the price of coal. Coal reserves are adequate for perhaps another century. Proven gas reserves are slightly in excess of 20 times current usage, with ultimate reserves predicted at some four times present reserves. Excluding the automotive use, petroleum products are by and large not competitive with coal in the domestic and industrial fuel market. Other sources of energy are not expected to be a regulating factor in the next ten years.

Because of increased mechanization including the rapid growth of strip mining techniques, the mine price of coal has been held relatively constant in the past ten years. Coal production during this period has varied up and down, but within relatively narrow limits. In comparison to this trend, the production of

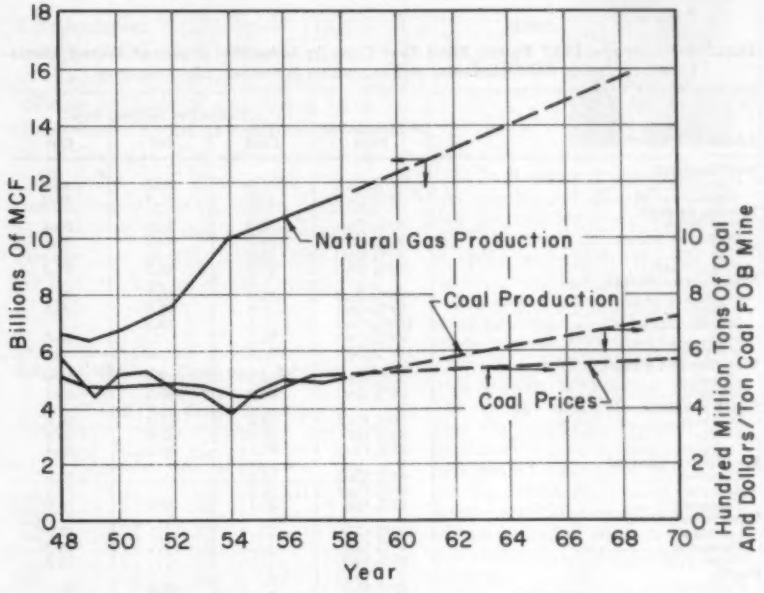


FIGURE 1—Production trends for gas and bituminous coal.

A Look Behind Natural Gas Prices . . .

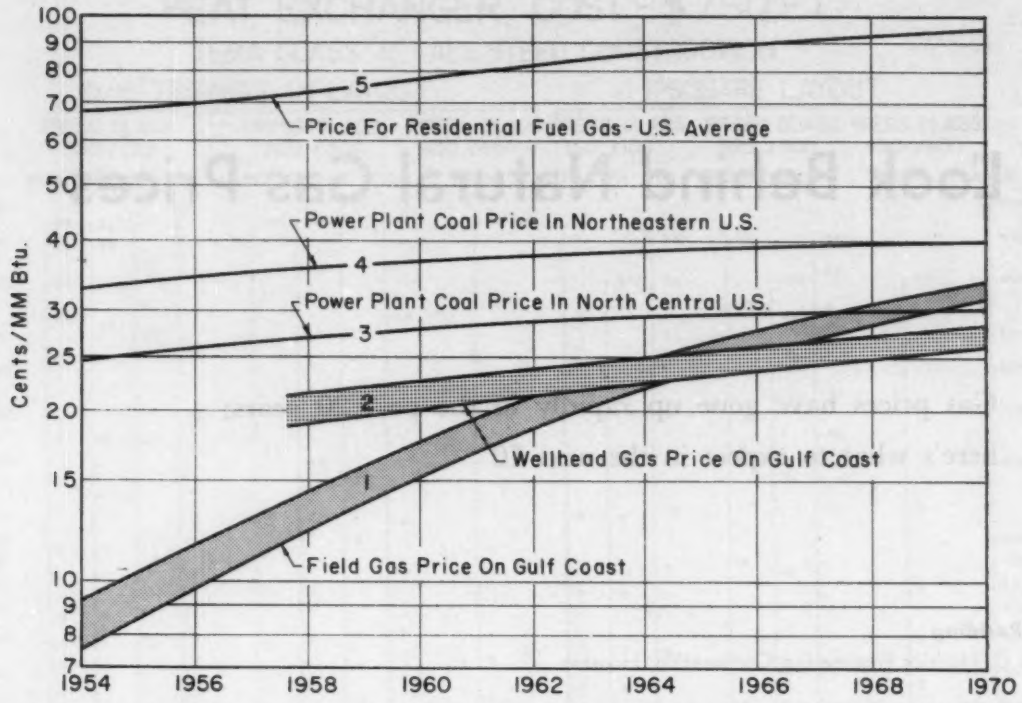


FIGURE 2—Price trends for gas and coal. (Curve 2 was extrapolated by using contract escalation on current prices.)

natural gas has doubled in the past ten years. These three factors are related in Figure 1.

Comparative Costs. With these relations in mind, it is interesting to see some comparative figures on fuel costs in sections of the country where the demand for fuel is generally concentrated. A good picture of the cost of fuel for the heavy industrial demand is available in the statistics of the power generating stations of the nation, as reported annually by the Federal Power Commission. In Table 1, average fuel costs for 1957 are presented for major industrial areas of the United States. The indication is not clear in these figures that coal is in position to control the heavy industrial fuel market in the heavily populated and industrialized sections of the nation. However, prices are so close now that coal should be in a control position in the future.

TABLE 1—Average 1957 Power Plant Fuel Costs in Industrial Areas of United States
Source: Federal Power Commission data as compiled by National Coal Association

AREA	Predominant Fuel	Cents Per Million Btu		
		Coal	Oil	Gas
New England				
Connecticut	84% Coal	40.0	49.7	42.0
Massachusetts	58% Coal	40.7	45.1	40.0
Middle Atlantic				
New Jersey	63% Coal	35.9	43.3	30.4
New York State	99% Coal	39.5	49.0	33.3
New York City	70% Coal	34.9	....	....
Pennsylvania	100% Coal	35.9	43.1	31.3
East North Central				
Illinois	88% Coal	25.0	63.7	23.1
Indiana	97% Coal	21.9	87.5	30.3
Michigan	100% Coal	32.1	76.5	....
Ohio	99% Coal	23.2	....	16.5
Wisconsin	100% Coal	33.1	....	....
West North Central				
Kansas	90% Gas	26.8	37.1	18.9
Missouri	65% Coal	24.6	45.8	20.1
South Atlantic				
Delaware	78% Coal	34.4	45.2	36.7
Florida	85% Oil	31.8	45.8	26.9
Georgia	51% Coal	29.1	50.2	23.4
East South Central				
Alabama	91% Coal	19.5	....	21.9
Kentucky	96% Coal	18.4	....	21.2
Tennessee	99% Gas	20.1	46.4	19.0
West South Central				
Louisiana	100% Gas	....	....	17.7
Oklahoma	100% Gas	....	....	13.2
Texas	100% Gas	....	....	12.2
Pacific				
California	55% Gas	....	41.4	26.4

In contrast to the industrial market, the domestic fuel and commercial fuel market presents an entirely different picture with regard to the effect of coal. Perhaps this can best be shown by reference to a tabulation of the relative costs of residential fuels in selected cities in the United States as presented in Table 2. The price advantage enjoyed by gas clearly indicates two important trends: gas will be the preferred fuel where supplies are available and secondly, there will be room generally for substantial increases in the price of natural gas delivered to the domestic user in significant areas of the United States.

Thus, it appears that we have two opposing effects working on the price

of gas. The heavy industrial demand, as illustrated by the public power companies, is well satisfied by coal at prices which gas cannot in some instances compete. At the other end of the demand scale, gas for residential use enjoys a greatly superior position and is not yet seriously restricted by competition. Between these two limits there are the many variations of commercial and light industrial demands with corresponding positions on the coal-gas relations.

The pattern for the growth of the natural gas industry in the northern and central states is well defined. The pattern in the Gulf south and Southwest today includes virtually all demands, residential and heavy industrial. The present consumption pattern for natural gas and one authoritative projection is set forth in Table 3.

Field Prices in Southwest. Perhaps we can now rationalize just a little on where the field prices in the Southwest and Gulf Coast regions are headed. We know that the following factors are all in favor of forcing the price of gas up:

1. Present and future demands for gas in the heavily populated and industralized areas of the United States.
2. Relatively non-competitive position of alternate fuels in the residential and similar markets.
3. The general trends of inflation.
4. The probable additional tax burdens to be placed on the production or transportation of gas by states or federal government seeking new sources of revenue.
5. The higher cost of finding and producing new gas reserves.

Against these forces, there appears only one which would tend to hold the prices down, and that is the possibility of additional but yet undefined course of legislature control. The effectiveness of such control on the overall trend is subject to much conjecture.

To see the probable trends in the prices of natural gas, certain basic and representative data are presented in Figure 2. The extensions to the year 1970 are at best considered opinions. The first data plotted as Curve 1 represent the trend on the average price paid for gas by a hypothetical gas company purchasing gas essentially on the Texas-Louisiana Gulf Coast.

The "average price" represents the composite of new and old contracts in effect. A similar hypothetical company purchasing gas in areas west and north of the Texas Louisiana Gulf Coast would probably follow a curve a few cents lower than this curve. Curve 2 is based on a review of a large number of recent gas purchase contracts. Curves 3, 4 and 5 were developed from the indicated sources. It is interesting to note that the 1958 national average wellhead price for natural gas is close to 11 cents per Mcf.

Conclusions. While these trends and predictions are certainly subject to variation in the limits shown, the relative positions of the curves leave little doubt about the future prices of natural gas. The spread between field price and the average residential revenue is shown to increase only slightly in the next ten years, largely due to the anticipated improved efficiencies of gas transportation. Virtually all of the factors previously mentioned which tend to increase the price of gas will be concentrated in the field prices for the gas.

The answer is what many have forecast. The field prices and the user prices are going to increase steadily. They can easily increase as much as these curves in Figure 2 predict.

TABLE 2—Cost of Residential Heating Fuels in U.S. Corrected for Differences in Efficiencies[1]

		CENTS PER MMBTU							
		Avg. 1946 1950	1951	1952	1953	1954	1955	1956	1957
Chicago	Bit. Coal	112.2	126.9	132.3	128.7	125.2	138.7	151.7	156.8
	Fuel Oil	173.0	186.8	186.8	193.3	193.3	199.3	207.2	207.2
	Gas	87.5	87.5	87.5	87.5	109.6	116.1	116.3	112.5
Cleveland	Bit. Coal	116.6	134.2	139.2	142.5	144.8	154.2	157.7	161.4
	Gas	63.4	64.0	65.5	71.4	71.4	71.4	78.0	78.8
Houston	Gas	67.8	67.5	67.5	69.0	69.3	69.5	70.3	71.4
New York	Anth. Coal	119.9	149.7	160.8	153.5	141.3	147.3	172.3	170.3
	Fuel Oil	147.7	161.0	172.1	174.0	182.6	184.2	195.2	191.8
	Gas	151.2	186.4	178.8	182.9	180.1	161.5	161.9	160.0
Pittsburgh	Bit. Coal	72.5	83.1	89.2	90.2	88.1	88.5	94.7	97.2
	Gas	60.6	60.3	64.4	66.4	69.8	72.8	74.3	76.8
San Francisco	Gas	42.4	43.5	56.8	56.9	56.9	61.5	61.5	61.5

Data Source: "Gas Facts-1957"

[1] These prices have been corrected on a differential efficiency basis with reference to gas, using the following efficiencies:

Gas:	80%
Anthracite:	62%
Bituminous:	59% (stoker fired)
Oil:	57%

TABLE 3—Projected Public Utility Gas Sales to Ultimate Consumers By Class of Service

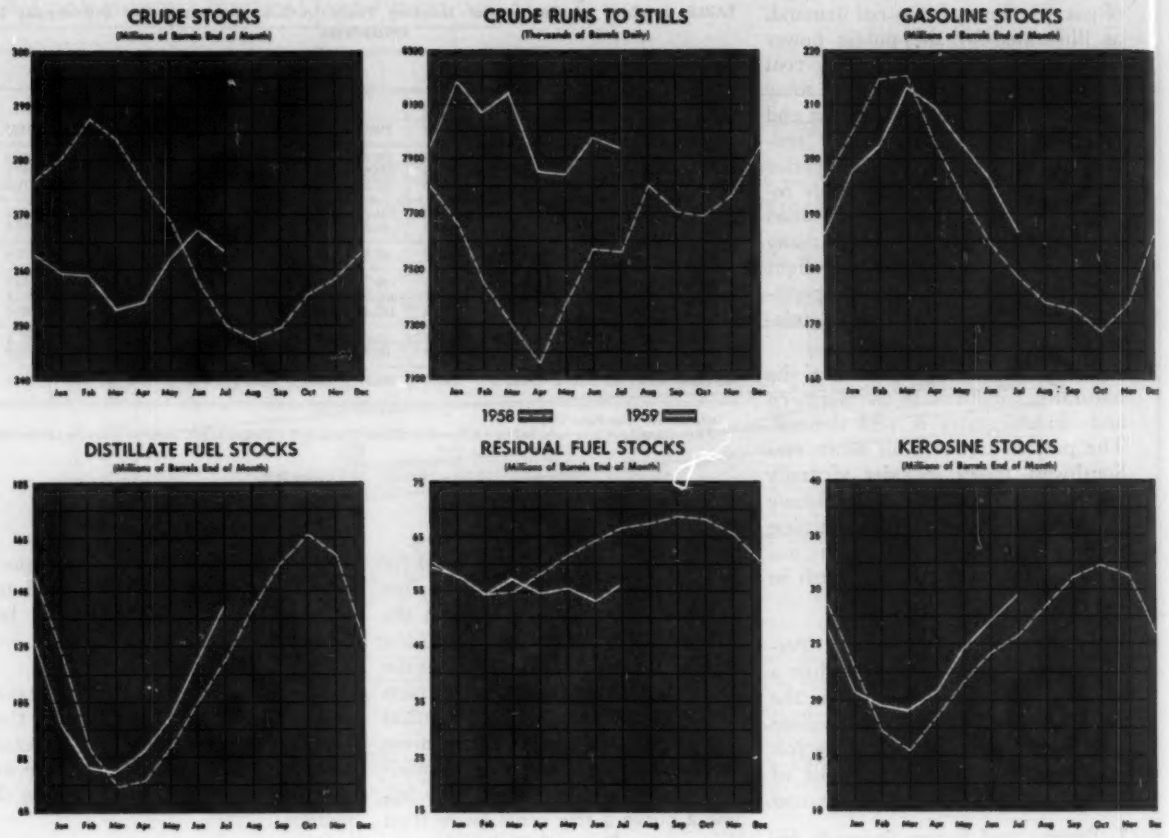
1958-1970—Billions of Mcf

	Residential	Commercial	Industrial	Total
1958	2.6	0.7	4.4	7.7
1960	3.1	0.8	5.1	9.0
1962	3.5	0.9	5.6	10.0
1964	4.0	1.1	6.1	11.2
1966	4.5	1.2	6.7	12.4
1968	5.1	1.4	7.4	13.9
1970	5.6	1.6	8.2	15.4

Based on American Gas Association Data and Projections.

About the Author

E. D. Redding is vice president and manager of Wyatt C. Hedrick Engineering Corp.'s Chemical Engineering Division. Holder of B.S. and M.S. degrees in chemical engineering from The University of Texas, he is a registered professional engineer. With Hedrick since 1951, Redding had 11 years' previous experience with Rollins & Forrest, Dallas; The Austin Co., Houston; The Dow Chemical Co., Freeport and McCarthy Interests, Houston. His background includes work in process design, evaluations for refineries and chemical plants, plant design, technical service, process development, construction and teaching.



Taking Stock

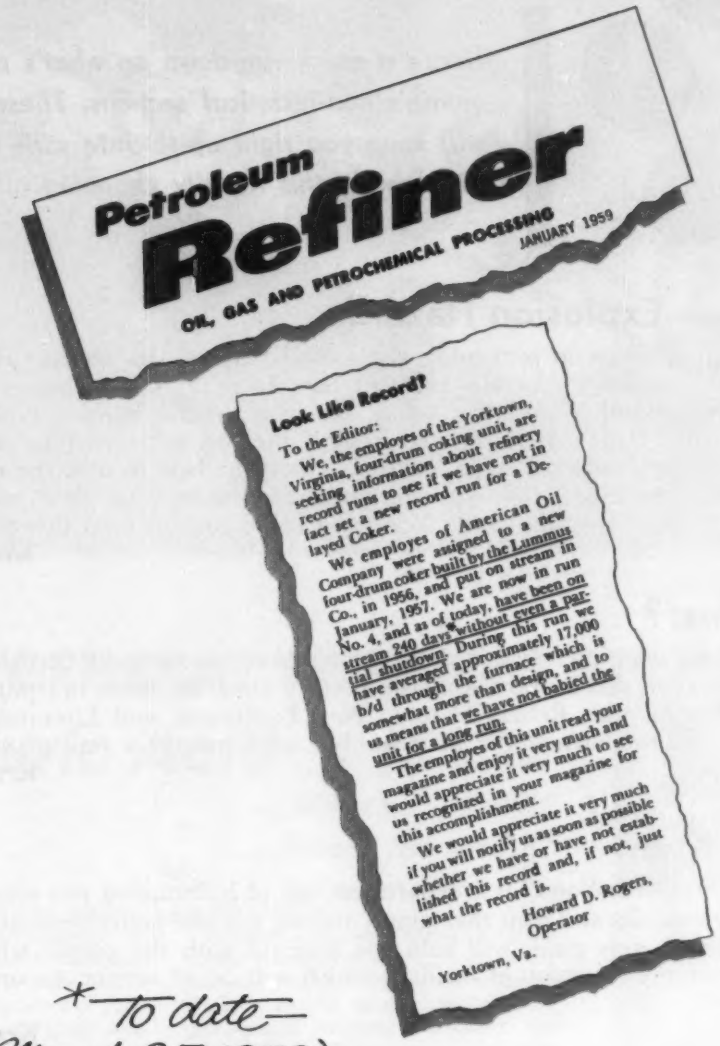
- Crude stocks dropping off
- Gasoline stocks down
- Residuals up again

U.S. Petroleum Demand and Supply (Thous. Bbls. Daily)

ITEM	July 1959	July 1958	July % Diff.	June 1959	January-July 1959	January-July 1958	January-July % Diff.
DEMAND							
All Oils, Total Demand	8,783	8,870	— 1.9	8,737	9,602	9,197	+ 4.4
Domestic Demand	8,453	8,557	— 1.2	8,487	9,351	8,925	+ 4.8
Export Demand	250	313	—20.1	250	251	272	— 7.7
Gasoline, Total Demand	4,436	4,303	+ 3.1	4,350	4,071	3,900	+ 4.4
Distillate, Total Demand	1,098	1,256	—12.6	1,162	1,874	1,850	+ 1.3
Kerosine, Total Demand	191	180	+ 6.1	186	300	310	— 3.2
Residual, Total Demand	1,221	1,315	— 7.1	1,378	1,681	1,498	+12.2
Other Oils, Total Demand	1,757	1,816	— 3.2	1,661	1,676	1,639	+ 2.3
CHANGE IN STOCKS							
All Oils, Change in Stocks	+319	+ 81	.....	+790	+185	—301	.....
NEW SUPPLY							
Total New Supply	9,022	8,951	+ 0.8	9,527	9,788	8,895	+10.0
Domestic Production, Total	7,701	7,341	+ 4.9	7,864	8,001	7,259	+10.2
Crude Oil	6,836	6,571	+ 4.0	7,002	7,130	6,480	+10.0
Natural Gas Liquids	865	770	+12.3	862	871	779	+11.8
Imports, Total	1,321	1,610	—18.0	1,663	1,787	1,637	+ 9.2
Refined Products	460	742	—38.0	494	846	708	+19.5
Crude Oil, Total	861	868	— 0.8	1,169	941	929	+ 1.3
Crude, East Coast	624	692	— 9.8	906	733	760	— 3.6
CRUDE RUNS							
Crude Runs to Stills	7,935	7,554	+ 5.0	7,993	8,036	7,462	+ 7.7
Domestic Crude	6,909	6,687	+ 3.3	6,949	7,085	7,085	+ 8.2
Foreign Crude	1,026	867	+18.3	1,044	951	916	+ 3.8

U.S. Stocks of Oils (Million Bbls. at End of Month)

KIND OF OIL	TOTAL IN U.S. July 1959	TOTAL IN U.S. July 1958	TOTAL IN U.S. % Diff.	TOTAL IN U.S. June 1959	EAST OF CALIFORNIA July 1959	EAST OF CALIFORNIA July 1958	EAST OF CALIFORNIA % Diff.	EAST OF CALIFORNIA June 1959
All Oils	819.9	776.0	+ 5.7	810.0	.....	.....	.....	.....
Crude Oil	263.7	246.6	+ 6.9	268.1	227.7	203.1	+12.1	233.9
Gasoline	186.2	180.7	+ 3.0	195.9	159.3	155.7	+ 2.3	167.0
Distillate Fuel Oil	139.8	119.4	+17.1	119.7	125.4	105.8	+18.5	106.5
Kerosine	29.3	25.7	+14.0	27.4	28.9	25.3	+14.2	27.0
Residual Fuel	55.8	66.5	—16.0	54.2	29.0	34.0	—14.7	28.1
Other Oils	145.1	137.1	+ 5.8	144.7	....	....	.....	....



Petroleum Refiner

OIL, GAS AND PETROCHEMICAL PROCESSING

JANUARY 1959

Look Like Record?

To the Editor:

We, the employes of the Yorktown, Virginia, four-drum coking unit, are seeking information about refinery record runs to see if we have not in fact set a new record run for a Delayed Coker.

We employes of American Oil Company were assigned to a new four-drum coker built by the Lummus Co., in 1956, and put on stream in January, 1957. We are now in run No. 4, and as of today, have been on stream 240 days without even a partial shutdown. During this run we have averaged approximately 17,000 b/d through the furnace which is somewhat more than design, and to us means that we have not babied the unit for a long run.

The employes of this unit read your magazine and enjoy it very much and would appreciate it very much to see us recognized in your magazine for this accomplishment.

We would appreciate it very much if you will notify us as soon as possible whether we have or have not established this record and, if not, just what the record is.

Howard D. Rogers,
Operator

Yorktown, Va.

* to date (March 25, 1959) their record now stands at 354 days..

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Valuable Reading Ahead

Here's a quick run-down on what's presented in this month's non-technical sections. These departments will keep you right up-to-date with what's new and different in this rapidly changing oil industry.

Beware Those Explosion Hazards

In addition to presenting the second part of the series, "How to Remember," this month's "As Management Sees It . . ." section brings you a highly interesting and informative safety article entitled, "Beware Process Explosion Hazards." This article contends that if the cost of preventing an explosion exceeds the probable cost of a disaster, it may be best to take the risk. It tells you how to determine if an explosion hazard exists in your plant, and if so, how much damage it would cause. You want to be sure to read this one so . . .

Keep going to Page 361

Want the Best?

As a man interested in doing what's most economically feasible to keep your plant modern and in top shape, you need to know the latest in equipment developments. The monthly Refiner feature, "New Equipment and Literature," will give you a quick rundown on the latest and best implements for your plant. To learn more . . .

Keep going to Page 449

You Should Know

"Suppliers Notes" is a department full of information you need to know about the companies and men that supply the oil, gas and petrochemical processing industry. This handy guide will help you keep up with the people who serve your plant, and any extension of facilities which will be of service to you. To see for yourself . . .

Keep going to Page 421

Knowledge is the Key

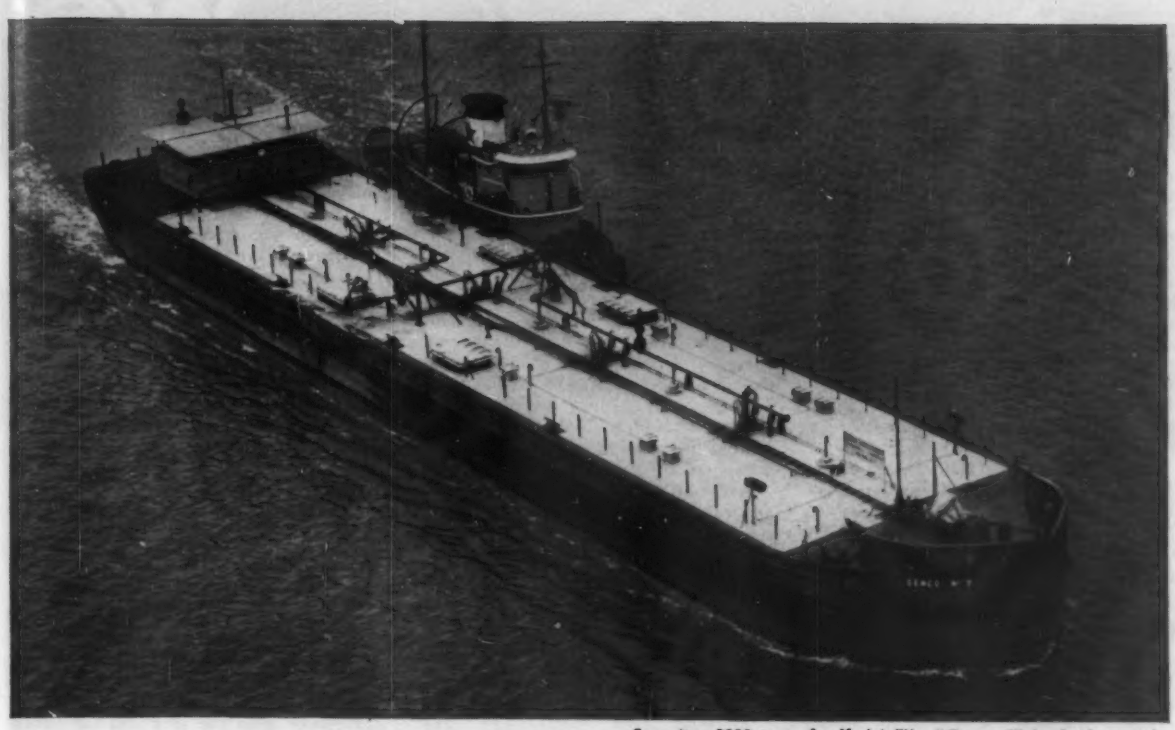
Knowledge is the key to success, at least one of them. And, what better way is there is to gain the knowledge you need to advance than by reading a good book or report on a subject important in your industry. If you would like to learn about some of the better publications hot off the press . . .

Keep going to Page 300

New Gimmicks

Somebody is always coming up with a new gimmick to save time, labor and the like. And, people are interested in this, which accounts for the popularity of the various "do it yourself" magazines. Well, PETROLEUM REFINER has a version of do-it-yourselfism for the Industry. To see for yourself what we mean . . .

Keep going to Page 310



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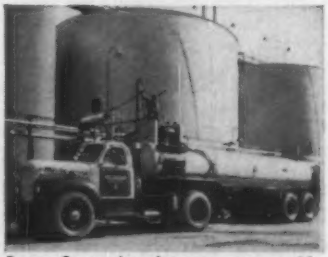
For example, we have eight sulfuric barges serving customers along the Atlantic coast and on inland waterways. Three operate out of Marcus Hook (Philadelphia), Pa. Two in the New York City area, including the 2000-ton capacity "Genco 7" shown above. Three on inland waterways. General also operates the largest fleets of sulfuric tank cars and tank trucks in the country.

General Chemical has 21 sulfuric plants,* as well as stock points in key industrial centers across the country. Each is geared to meet regional requirements, offering customers the advantages of "next door" location to General's modern facilities. In addition, the output of one plant backs up that of another, making a coast-to-coast supply line which proves invaluable in meeting emergencies or unexpected demands.

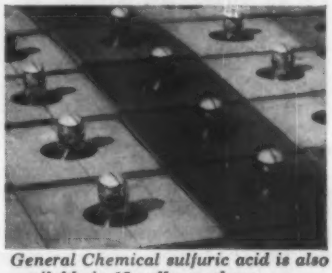
Why not find out how our long experience and extensive facilities can benefit you? For further information, write or phone the nearest General Chemical sales office.

**In Canada: Allied Chemical Canada, Limited*



Large fleets of tank transports provide fast over-the-highway service.

By far the largest fleet of sulfuric tank cars is operated by General Chemical.



General Chemical sulfuric acid is also available in 13-gallon carboys.

Allied Chemical

GENERAL CHEMICAL DIVISION
40 Rector Street, New York 6, N. Y.

For more data on advertised products, use Readers' Service Cards, last page.

New Books...

Free-Radical Chemistry

"Vistas in Free-Radical Chemistry" contains appreciations of the achievements of American chemist Morris S. Kharasch, of Chicago University. Included are reprints of historical papers, critical reviews of the origins and implications of Kharasch's discoveries in the chemistry of free-radicals. It also gives a collected bibliography of his publications.

The volume surveys the major advances in free-radical chemistry over the last past 30 years, contains original scientific papers, and indicates probable future trends.

(Waters, W. A. (Editor), *Vistas in Free-Radical Chemistry,* Pergamon Press, Inc., 122 East 55th St., New York 22, N. Y., 251 pages, $12.50. For sale by Gulf Publishing Co., P.O. Box 2608, Houston 1, Texas, U.S.A.)

Industrial Solvent Book

"Source Book on Industrial Solvents, Volume 3," presents the physical properties, azeotropic mixtures and uses of industrial alcohols. A historical survey leads up to present-day synthesis—Fischer-Tropsch, Isosynthesis, Oxo Process and the Oxyl Process. Methods of manufacture and newer methods of fermentation are also discussed. The book includes many significant figures and tables.

(Mellan, Ibert, *Source Book of Industrial Solvents,* Reinhold Publishing Co., 430 Park Ave., New York 22, N. Y., 276 pages, $10. For sale by Gulf Publishing Co., P.O. Box 2608, Houston 1, Texas, U.S.A.)

Carbon Conference Report

"Proceedings of the Third Conference on Carbon" contains the papers presented at the Carbon Conference, which established a meeting ground for physicists, chemists, and technologists interested in carbon, its production and applications. Aspects of the subject covered are solid state physics, chemistry of solid carbon compounds and reactions, irradiation effects and studies of the properties of resulting products as a function of processing variables.

The publication contains extensive reviews of recent major advances in carbon research, and the proceedings represent an international survey of the field. There are contributions from such eminent scientists as C. A. Coulson of Oxford, A. R. Ubbelohde of Imperial College, and J. R. Platt of Chicago—and papers from Australia, United Kingdom, France, Japan, Canada, Belgium, Germany and the United States.

(Proceedings of the Third Conference on Carbon, Permagon Press, Inc., 122 East 55th St., New York 22, N.Y., 718 pages, $20.00. For sale by Gulf Publishing Co., P.O. Box 2608, Houston 1, Texas, U.S.A.)

Solubility Diagram Survey

"Survey of Solubility Diagrams for Ternary and Quaternary Liquid Systems" is a thorough literature survey of all of the water and organic liquid systems which have been published prior to June, 1958, in a wide variety of periodicals, text books, and industrial publications.

Solubility data have become more abundant each year and, at the same time, become buried in a mass of other data which conceal and frequently obliterate them. A quick inspection of this reference table will show whether the desired information exists. The following groupings are presented:

- Group 1. Systems containing water and two organic compounds with a cross reference between the most common systems.
- Group 2. Non-aqueous organic systems with cross references.
- Group 3. Systems containing liquid propane and two non-aqueous components.
- Group 4. Quaternary systems.
- Group 5. Systems containing water, one organic liquid and one metallic-organic compounds.

(McKetta, J. J., Bray, B. L. and Himmelblau, D. M., *Survey of Solubility Diagrams for Ternary and Quaternary Liquid Systems,* Bureau of Engineering Research, The University of Texas, Austin 12, Texas, 43 pages, $2. For sale by Gulf Publishing Co., P.O. Box 2608, Houston 1, Texas, U.S.A.)

Radioisotopes for Industry

"Radioisotopes for Industry" answers the question of how to apply radioisotopes to a vast number of particular problems. The applications described in this book are specific and suggest many new uses. Sufficient material is included with each description so that the reader can project the examples into his own needs. In addition to uses, the authors also include discussions of personnel safety, facilities for handling radioisotopes, and setup costs.

(Rochlin, R. S., and Schultz, W. W., *Radioisotopes for Industry,* Reinhold Publishing Co., 430 Park Ave., New York 22, N.Y., 190 pages, $4.75. For sale by Gulf Publishing Co., P.O. Box 2608, Houston 1, Texas, U.S.A.)

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For a free copy of our book catalog write to BOOK DEPARTMENT, GULF PUBLISHING COMPANY, P. O. Box 2608, Houston 1, Texas. Often books reviewed here may be purchased from this source.

Process Equipment Design

"Process Equipment Design" acts as a guide to vessel design by unifying the basic concecpts, industrial practices, and analytical relationships that are used. The book has been planned around the basic tenet that the vessel is the principal part of most types of processing equipment. The fundamenatl relationships on which many of the ASME code specifications are based have been developed. The last two chapters concern the design of vessels beyond the pressure limitations of the ASME code.

The material ranges from simple vessels for low-pressure and vacuum service to thick-walled vessels for high-pressure applications.

(Brownell, L. E. and Young, E. H., *Process Equipment Design,* John Wiley & Sons, Inc., 440 4th Ave., New York 16, N.Y., 408 pages, $19.50. For sale by Gulf Publishing Co., P.O. Box 2608, Houston 1, Texas, U.S.A.)

Computer Applications

"Proceedings of the Fifth Annual Computer Applications Symposium" (1958) provides a medium for discussing the applications of computer technology from the user's standpoint. Emphasis is on the user and the various ways he can benefit from knowledge of new techniques, developments and areas of application. The publication includes 14 papers presented at the conference, plus transcripts of panel discussions at the conclusion of each day's technical sessions.

(Illinois Institute of Technology, *Proceedings of the Fifth Annual Computer Application Symposium (1958),* Armour Research Foundation, Main Files: CA-5, 10 W. 35th St., Chicago 16, Ill., 153 pages, $3.)

Gas Engineering Handbook

"Handbook of Natural Gas Engineering" presents, in one comprehensive volume, the information required by engineers practicing in the natural gasoline industry. The book treats natural gasoline in its various stages, from occurance in the reservoir through production, processing, and transportation to the ultimate consumer. Primary consideration is given to the properties of hydrocarbons and the applications of these properties in flow and processing operations.

The book covers a full range of topics —from the very practical to the very theoretical. The first chapters give basic information required by the practicing engineer. A considerable amount of quantitative data in the form of charts, tables, and formulas is presented to serve as a basis for design calculations. Quantitative methods are utilized whenever available.

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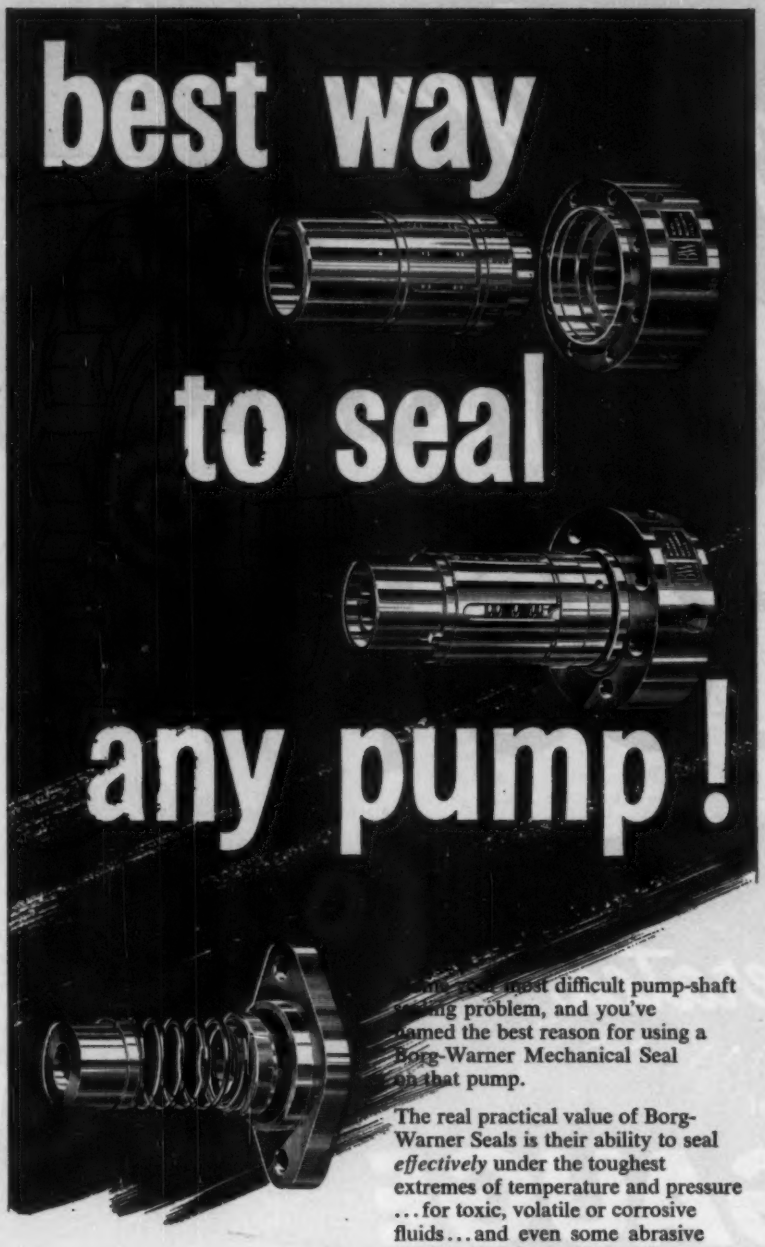

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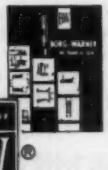

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fice meters. There are about 840 illustrations.

(Katz, D. L., et al, *Handbook of Natural Gas Engineering*, McGraw-Hill Book Co., 330 West 42nd St., New York 36, N. Y., 802 pages, $37.50. For sale by Gulf Publishing Co., P.O. Box 2608, Houston 1, Texas, U.S.A.)

Managing A Small Company

"Management for the Smaller Company" is a reference book created specifically for companies with fewer than 1,000 employes. It is based on the knowledge and experience of executives and specialists who have actually solved small-company problems. This publication offers checkpoints for comparing present company performance with the achievements of others. It explains techniques for building the strong reserve of managerial talent so essential to the smaller company and discusses many aspects of personnel administration. Top executives with managerial know-how analyze problems in marketing, manufacturing, and finance. Specialists deal with the expanding area of research and development, showing how the smaller company can budget a product program, and how it can obtain and evaluate new product ideas. This book explains where—and when—the smaller company can look for outside resources such as government assistance, management consultants, and new management techniques like operations research. In addition, it contains a comprehensive reading list of where to obtain other publications on small business, texts on management topics, and pertinent government publications.

(Marting, Elizabeth, *Management for the Smaller Company*, American Management Association, 1515 Broadway, Times Square, New York 36, N. Y., 399 pages, $9 or $6 for AMA Members.)

Adventure in Oil

"Adventure in Oil" is the story of an enterprise which began at the turn of the century in the barren wastes of Southwest Persia, and today produces, sells or searches for oil in almost every country of the free world. The British Petroleum Co., which celebrates its 50th anniversary this year, plays the leading part. The author prepared this book as a story not of a company but of a people. The book's worth is emphasized in a foreword by Sir Winston Churchill.

(Longhurst, Henry, *Adventure in Oil*, Sidgwick and Jackson Publishers, London, 286 pages, $3. For sale by Gulf Publishing Co., P.O. Box 2608, Houston, Texas, U.S.A.)

Unusual Chromatograph

"Design and Construction of a Gas-Liquid Partition Chromatographic Unit, and its Application to the Quantitative Analysis of Liquid Solutions" (PB 151008) discusses chromatograph constructed for easy separation and analysis of water-alcohol solutions. Installed in a commercial-type relay rack, the unit fea-

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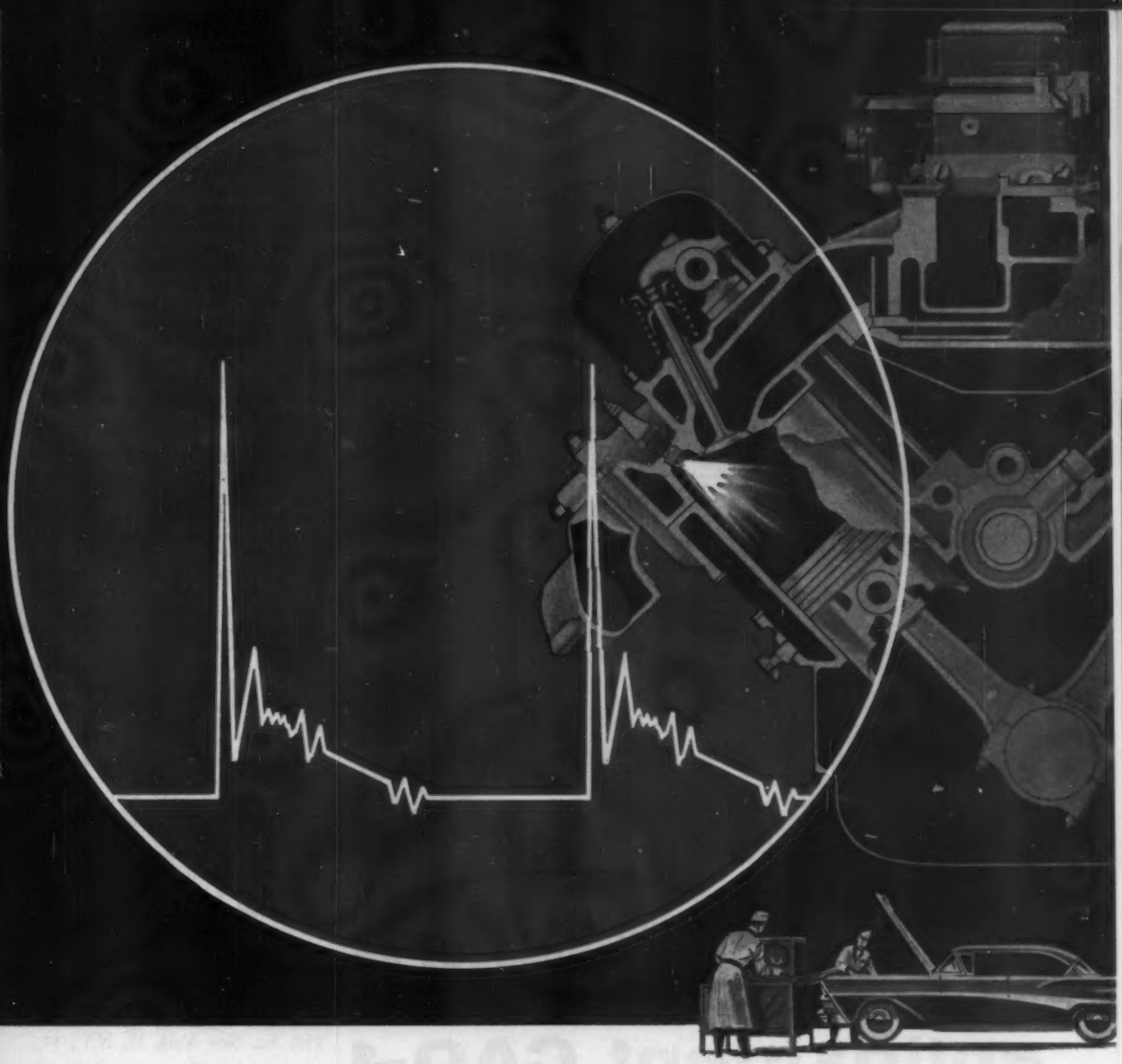

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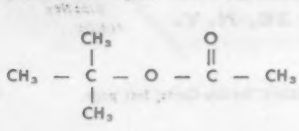
Physical State	Colorless liquid
Odor	Pleasant
Solubility in H_2O at 77° F, %	0.6



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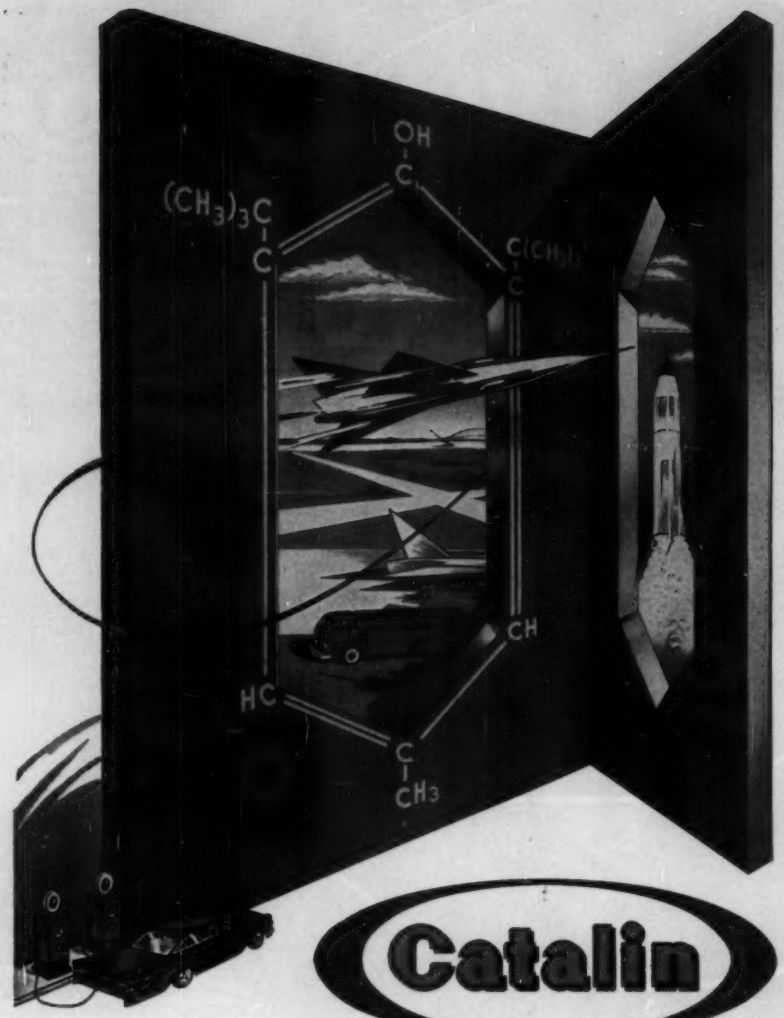

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tures a specially constructed control panel, a sample-injection system, and a thermal conductivity cell. The apparatus was used for quantitative analysis of ethanol-water-ether, carbon tetrachloride-acetone, ethanol-chloroform, and carbon tetrachloride-chloroform solutions.

(Browning, L. and Watts, J. O., *Design and Construction of a Gas-Liquid Partition Chromatographic Unit, and its Application to the Quantitative Analysis of Liquid Solution* (PB 151008), Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C., 42 pages, $1.00.)

Refining Piping Code

"American Standard Petroleum Refining Piping Code, ASA B31.3-1959," has been published. It appears separately from the rest of the American Standard Code for Pressure Piping, ASA B31.1-1955, of which it used to form a part of Section 3. Although the revision is still part of the code, its new size made separate publication a necessity for easier reference and handling. In its new form, the code has been extensively revised and brought up to date, and many additions have been made. An orderly procedure has been set up for interpretation and proposed revision of the code through the issuance of "cases."

In general, Section 3 covers all piping within the property limits of a petroleum refinery, loading terminal, gas processing plant, bulk plant, compounding plant, or refinery tank farm, as well as interconnecting lines between separate sections of a refinery. It applies to all fluids, including fluidized solids, and to all types of services, including oil, gas, steam, air, water, chemicals, and refrigerants.

(ASA, *American Standard Petroleum Refining Piping Code*, ASA B31.3-1959, American Standards Association, 70 E. 45th St., New York 17, N.Y., $4.)

Labor Relations Guide

"Labor-Management Relations" covers the actual day-to-day problems a company must face in dealing with employes and trade unions. It emphasizes the importance of proper labor contract language, and debunks the molifying approach to employes as a progressive management attitude. The book also includes the effect that emotions have in labor relations, the particular problems of the union shop, "right to work" laws and strikes.

(Wiedemann, Charles, *Labor-Management Relations*, Reinhold Publishing Co., Corp., Dept. B-293, 430 Park Ave., New York 22, N.Y., 142 pages, $3.75. For sale by Gulf Publishing Co., P.O. Box 2608, Houston 1, Texas, U.S.A.)

Thermodynamics

"Thermodynamics" covers both the physical and mathematical aspects of thermodynamics. Written for the undergraduate level of study, it gives a rigorous treatment of fundamentals along with a distinctly engineering perspec-

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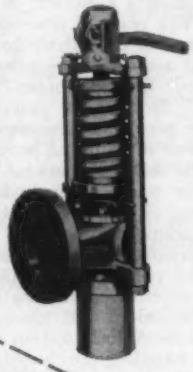

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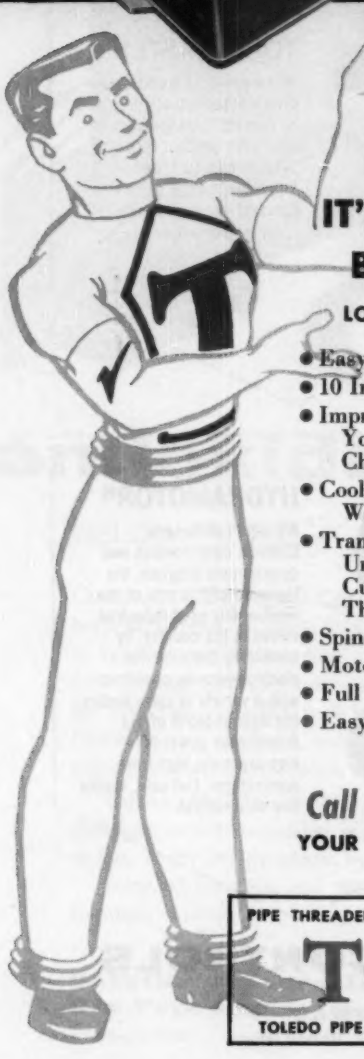

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tive. The analysis of the first law of thermodynamics includes flow into an open system. Then, the second law is developed in the classical manner, while the gas tables of Keenan and Kaye are used as examples of tabulated thermodynamic data.

After covering the concepts of availability and irreversibility, the author delves into typical processes such as reciprocating machinery and refrigeration cycles. The coverage is completed with a treatment of chemical reactions and equilibrium.

(Van Wylen, Gordon J., *Thermodynamics,* John Wiley & Sons, Inc., 440 4th Ave., New York 16, N.Y., 567 pages, $7.95. For sale by Gulf Publishing Co., P.O. Box 2608, Houston 1, Texas, U.S.A.)

Process System Analysis

"Continuous Analysis of Chemical Process Systems" presents details on all phases of the new analytical devices designed to attain economical, accurate, and continuous monitoring of chemical process systems. Information in the book, collected from journals, commercial literature, and personal communications, has been reviewed and approved by the instrument companies manufacturing continuous analytical devices, and is therefore considered authoritative and up-to-date.

Each instrument is described according to principle of operation, range of application, accuracy and precision, installation and construction specifications, time for response, use with controllers, versatility, and interreferences.

(Siggia, Sidney, *Continuous Analysis of Chemical Process Systems,* John Wiley & Sons, Inc., 440 4th Ave., New York 16, N.Y., 381 pages, $8.50. For sale by Gulf Publishing Co., P.O. Box 2608, Houston 1, Texas, U.S.A.)

The Personnel Function

"The Personnel Function: A Progress Report" offers realistic new approaches to the personnel executive's basic questions: What are my decision-making responsibilities? Can personnel work be "scientific?" Is there a practical philosophy for personnel administration?

Solutions to these broad problems are suggested in this publication. Ways of applying the scientific method in personnel work, of charting the course of personnel administration, and of improving employment relationships are described by personnel specialists. The book also reviews recent data on compensation, appraisal, and labor-management relations. A final section describes methods of handling the "problem" employe: how to deal with emotional disturbances in industry, how to turn emotional handicaps into assets through job change, etc.

This book will be of interest to executives who wish to keep informed about current developments in industrial relations.

(AMA, *The Personnel Function: A Progress Report, (No. 24)* American

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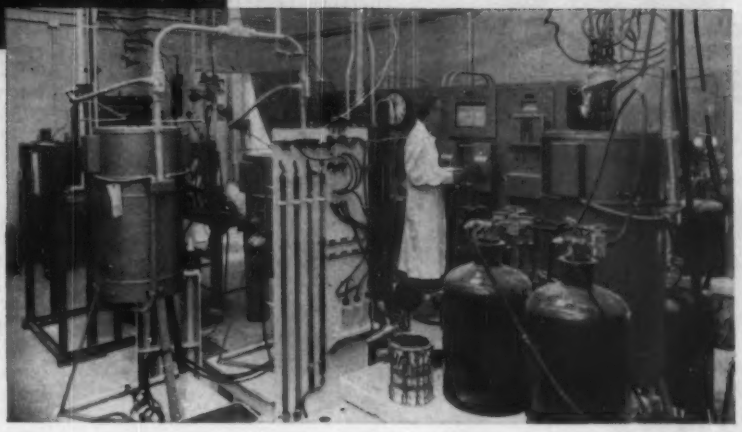

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Management Association, 1515 Broadway, Times Square, New York 36, N. Y., 140 pages, $3.75 or $2.50 for AMA Members.)

Maintenance, Engineering

"Techniques of Plant Maintenance and Engineering" is a report on the technical sessions held concurrently with the 1959 Plant Maintenance and Engineering Show, Cleveland. One of the major features of the book is the vast number of practical situations it covers. Included are answers to 1,056 questions submitted by engineers attending the conference. More than 70 charts, graphs and diagrams are reproduced.

Particularly valuable are reports of sessions confined to single industries. These include discussions on maintenance in nuclear plants, research and development laboratories, abrasive product plants, foundries, pulp and paper mills, assembly plants, chemical plants, electrical manufacturing plants, metal working and metal fabricating plants, and petroleum refineries.

(*Plant Maintenance and Engineering*, Clapp & Poliak, Inc., 341 Madison Ave., New York 17, N.Y., 266 pages, $10. For sale by Gulf Publishing Co., P.O. Box 2608, Houston 1, Texas, U.S.A.)

American Water Technology

"Technology in American Water Development," the result of a three-year study, reviews the past and prospective changes in technology that bear upon water-supply demand and management. It examines the • impact upon administrative patterns and policy decisions. The book has four sections:

- The Physical and Economic Environment of Water Development.
- Techniques and Technical Events Significant in the Progress of Water Development.
- Emerging Technology of Potential Impact on Water Use.
- Organizational Responses to Problems and Opportunities for Water Development Introduced by Technologic Change.

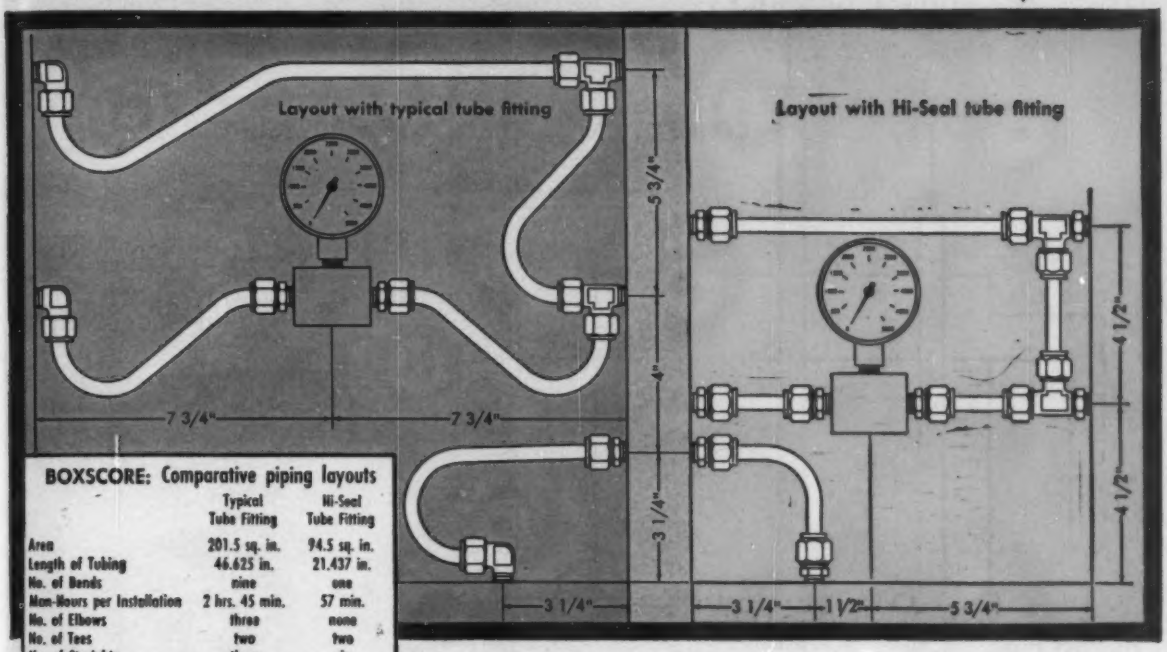
The emerging techniques described and evaluated include demineralization, weather modification, improved thermal generation of electricity, and industrial recycling.

(Ackerman, E. A., and Löf, G. O. G., *Technology in American Water Development*, The Johns Hopkins Press, Baltimore 18, Md., 720 pages, $10.00.)

Now turn to page 310 and read "How To Do It" for handy, inexpensive items you can make for your plant.

IMPERIAL *Engineering and Data File*

ENGINEERED TUBE FITTINGS — VALVES — TUBING TOOLS



BOXSCORE: Comparative piping layouts

	Typical Tube Fitting	Hi-Seal Tube Fitting
Area	201.5 sq. in.	94.5 sq. in.
Length of Tubing	46.625 in.	21.437 in.
No. of Bends	nine	one
Man-Hours per Installation	2 hrs. 45 min.	57 min.
No. of Elbows	three	none
No. of Tees	two	two
No. of Straights	three	six

How Hi-Seal saves space—cuts costs

. . . makes possible reductions up to 50% in required piping area . . . up to 66⅔% in installation time!

Imperial Hi-Seal tube fittings open up economical *new piping design concepts* for instrumentation, hydraulic circuits, and other tubing installations. Hi-Seal makes possible far more compact layouts than can be made with conventional fittings — in addition, it brings *new ease and speed* to joint making and utmost reliability.

These design considerations are illustrated in the tubing layouts above. The diagrams show how Hi-Seal actually eliminated nine tube bends . . . saved more than one-half on tubing needed. Total layout area required by Hi-Seal is only 94.5 sq. in., compared to 201.5 sq. in., when an ordinary fitting is used. And 189% *more* manhours were required to tube up the circuit with a typical fitting.

Several key fitting design factors account for Hi-Seal piping economies: (1) Hi-Seal makes a positive butt joint — no need to spring tubing; (2) speedy, foolproof assembly — it is impossible for the fitting to be assembled with the alloy steel sleeve in reverse position; (3) there is no danger of over-torqueing . . . when threads on body of fitting are covered, a pressure-tight seal has been made, a visual assurance of a correct joint; (4) under tests, Hi-Seal fittings have withstood pressure of 4,000 psi at conditions of −320° F. to over 700° F.

with *no* leakage; (5) Hi-Seal fittings can be disconnected and reconnected as often as desired.

Complete line — Hi-Seal fittings are available in brass, steel, stainless steel. Also furnished in Titanium, Tantalum and other metals. Steel fitting supplied with cadmium plate or black phosphate finish. Conform to J.I.C., A.S.M.E. and A.S.A. standards. In sizes for ⅛" to 1½" O.D. tubing. Furnished with Long Dryseal pipe threads or straight thread port seal.

Write for Bulletin No. 3061

IMPERIAL

THE IMPERIAL BRASS MFG. CO.
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New high-pressure valves assemble directly to tubing — eliminate additional fittings

A revolutionary new line of Imperial needle valves designed for working pressures up to 5,000 psi., and temperatures to 450° F., employs Hi-Seal tubing connections.

Write for Bulletin 3096, or Catalog No. 200

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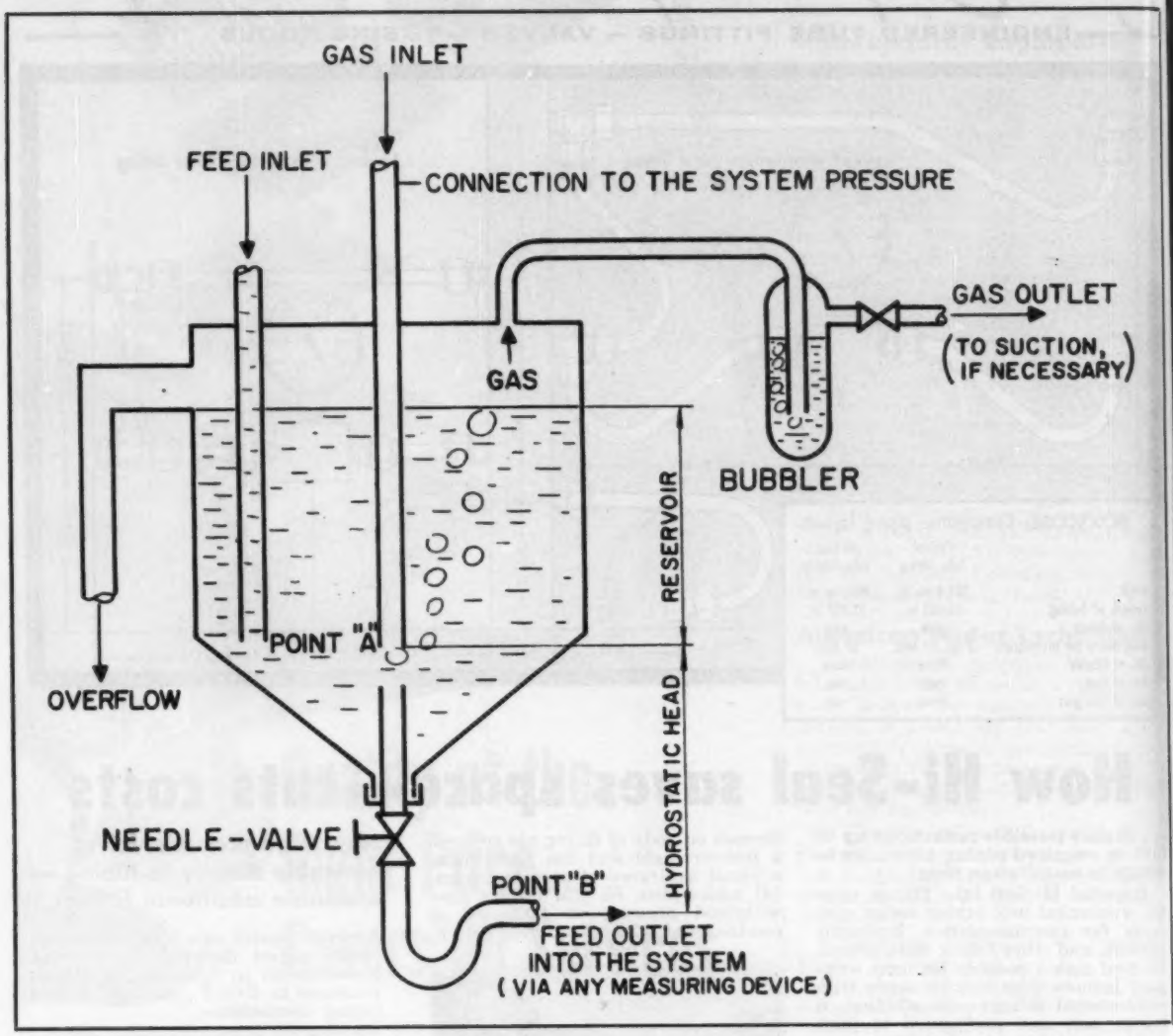


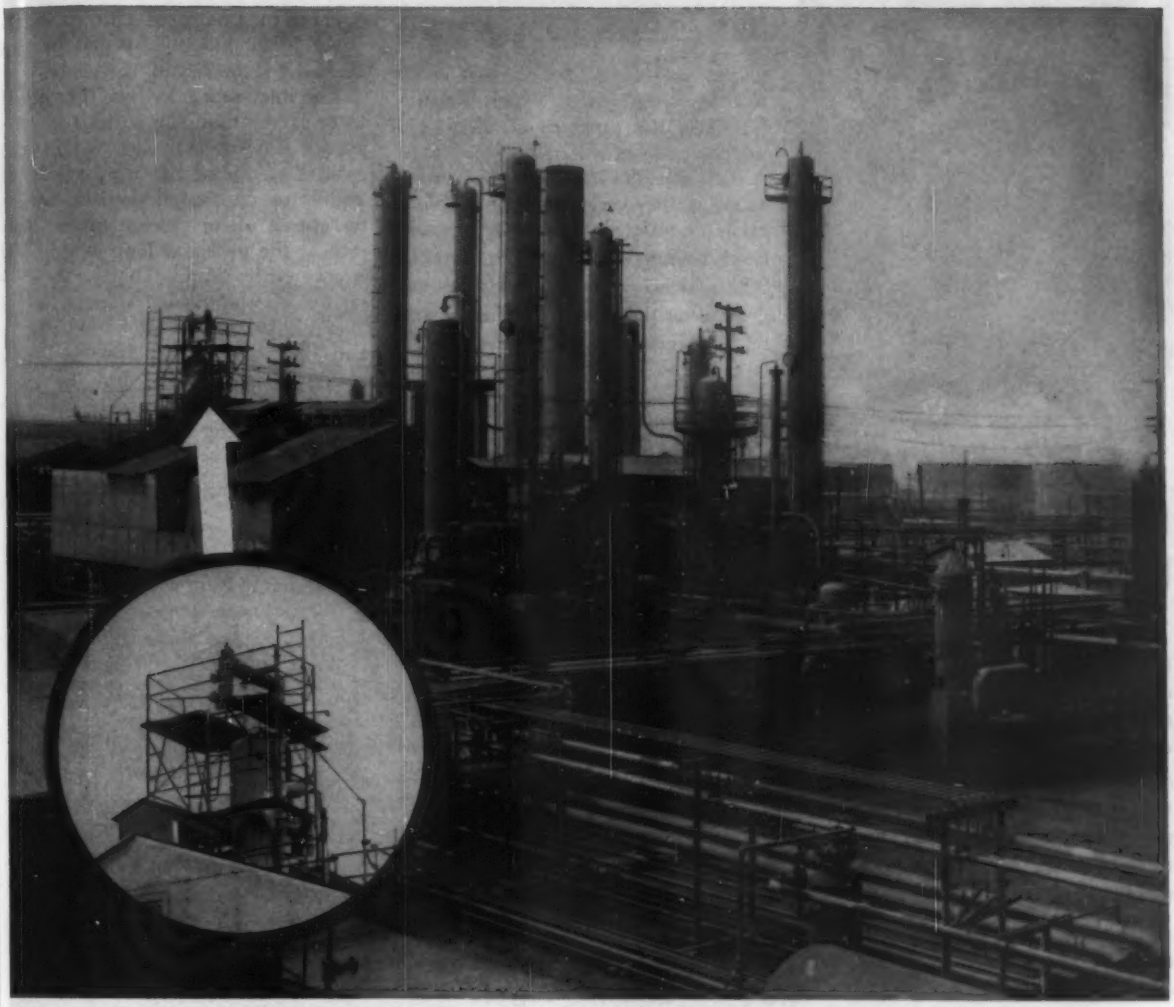
Constant Feed Using Marriot's Bottle

If you have a nonconstant feed supply, try this easy method to smooth out the feed rate

If you need to supply feed to a system operating at a pressure other than atmospheric, at a rate which is constant and independent of variations in the system, try this idea.

Examples of the application are: Changes in system pressure, non-constant feed supply, variations in the distillate rate (in the case of a distillation column operating under total or partial reflux) etc. A device based on the principle of Marriot's bottle may come in handy (see figure).

Since air (or any other gas) is drawn or forced out of the vessel constantly, at a slow rate (which may be inspected and regulated according to the amount of bubbling), it enters the vessel at the same rate through the tube connected to the system pressure. Thus, the latter is



New, nickel-lined butane reactor resists catalyst attack, handles 3500 bbls/day at Shell Oil Company plant, Wilmington, Calif. Pumps, lines, vessels contacting aluminum chloride catalyst are also Nickel.

New reactor boosts butane conversion 18%

...Nickel lining checks catalyst corrosion

Shell Oil Company recently revealed a new butane isomerization reactor that raises yields and reduces equipment requirements. The new reactor boosts conversion of normal butane to isobutane from 51% to about 60%. Shell engineers also estimate that, if designed into a new liquid phase isomerization unit, capital investment costs would be 15% less.

In the Shell process, normal liquid butane is dewatered, heated, scrubbed, fed into the reactor. Here, in contact with a liquid catalyst of aluminum chloride in antimony chloride, it is converted to isobutane.

The reactor has to withstand a highly corrosive combination – hydrogen chloride, metal chlorides, sulfur traces . . . too much for ordinary metals to handle. Shell's designers specified Nickel to check corrosion. The reactor and all pumps, lines and vessels contacting the catalyst are Nickel or nickel-lined to insure against corrosion failure.

Acid chlorides your problem? Tell us about it. We'll be glad to help you with the results of our plant and laboratory corrosion studies.

The International Nickel Company, Inc.
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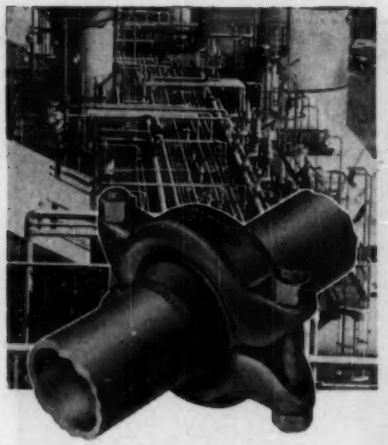
INCO NICKEL ALLOYS



GRAYLOC

New Principle of Pipe Connections

Two-bolt GRAYLOC Pipe Connections introduce a new principle in pipe make-up. Its design makes it possible for GRAYLOC to withstand full vacuum, high external pressure and extreme internal pressure. Moreover, this design makes it possible to make up GRAYLOC Connections repeatedly with no wear or other damage to the connections.

The bolting carries no primary force from internal pressures. Two bolts serve only to pull the connection together through the wedging action of the clamp and the seal ring.

Flexible tapered lips of the seal ring are angled slightly less than the mating hub. This forms a line seal which is changed to a surface seal as the connection comes together and the lips deflect.

GRAYLOC has practical uses in any application where flanges are used. GRAYLOC is recommended where pressures are high or where you want savings in money, space, weight or time.

For additional information, write, wire or telephone Gray Tool Company.

GRAY *Tool Company*

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REpublic 4-1641 5903

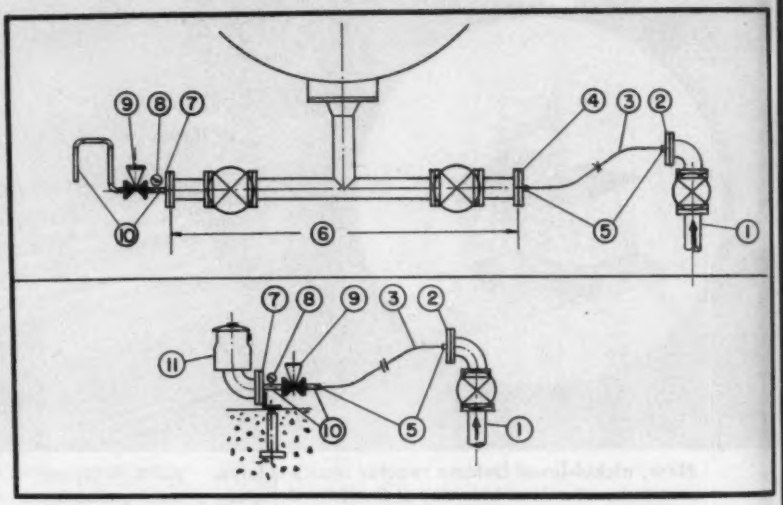
How To Do It . . .

always full of gas at a pressure equal to that of the system, which is therefore also the pressure of the liquid at the height of the tube's end (Point A). As the liquid enters the system at point B, where the same pressure exists, it follows that the hydrostatic head is determined by the distance AB (which is constant) and does not depend on the liquid level in the vessel as long as point A is covered with liquid.

The outlet rate is regulated by means of the needle valve, and as the hydrostatic head AB can be made quite small, a large needle-valve opening may be used. Thus, it is unlikely to be blocked by grit or dirt carried by the liquid.

The inlet rate may be either equal to or larger than the outlet rate, the excess leaving as overflow. In the case of a break in the supply of liquids to the vessel, there is no interruption of, or change in the flow rate at the outlet as long as point A is covered by liquid. That is, the vessel may be built so that the volume of liquid between the overflow outlet and the point A, which serves as a reservoir, is sufficient for the estimated duration of any interruption or reduction in the entry rate.

This idea was submitted by Tuvia Zisner, Rehovoth, Israel.



Make Own Tank Car Hydro-Test Equipment

The first rule for tank car safety is: "Special care should be taken to prevent destruction of the tank and to prevent any possible leakage." It is clear, from the rule, that the most important factor is the prevention of leakage because, if this is done, most accidents can be prevented.

An old tank car maintenance procedure stated: "The tank cars shall be fully filled with water for leak testing." This procedure has been found unsatisfactory for testing weak points in the tank because the latter is subject to severe vibration during transportation and shock when cars are coupled. Therefore, it has been decided that a hydraulic pressure test should be devised to inspect the tanks for leaks.

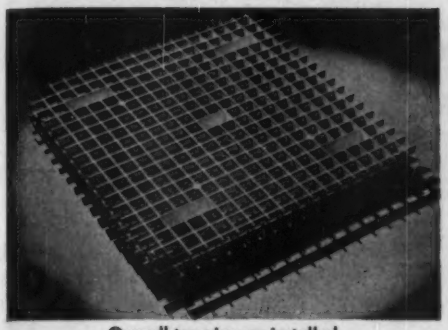
Analysis. The maximum operating pressure of the tank car is the safety valve pressure, 25 psi. Therefore, a high-pressure water source, 30-40 psi, would be satisfactory for testing.

- The pressure test gage should be located at the bottom of the tank to measure the greatest system pressure.
- A hand operated emergency relief valve should be located near the pressure gage.
- The open end of the discharge line should be a goose neck to prevent air from entering the tank.

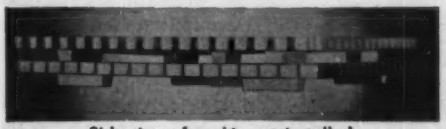
Material Needed. To make the test device, use the following material to be connected to a 3-inch high-pressure water line (item #1 in the upper figure):

announcing

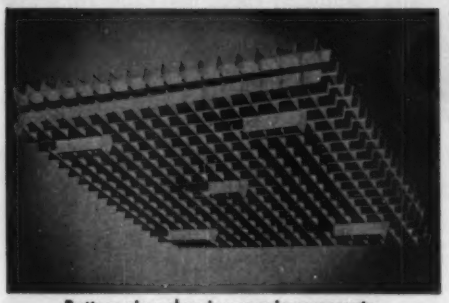
FLUOR'S NEW *poly-* GRID



Overall top view as installed



Side view of packing as installed



Bottom view showing spacing supports

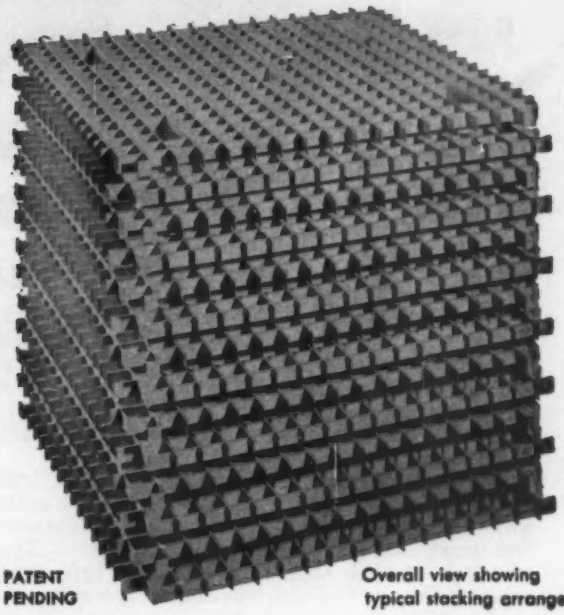
MORE COOLING IN YOUR EXISTING TOWER . . .

To increase the throughput of your existing counterflow induced draft cooling tower, Fluor Products Company now offers "Poly-Grid" packing.

This revolutionary packing provides greater cooling surface — greater overall heat transfer; yet construction is open, and pressure drop low.

"Poly-Grid" is available in high impact polystyrene or linear-polyethylene to meet all water conditions.

Fluor "Poly-Grid" packing allows you to cool more water under existing operating conditions, or to realize extra cooling of present throughput — all at minimum capital expenditure.



PATENT PENDING

Overall view showing typical stacking arrangement

Contact your nearest Fluor Representative for details.

POLY-GRID can be easily installed in any counterflow induced draft cooling tower—regardless of make or model!

Call him today!

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A DIVISION OF THE FLUOR CORPORATION, LTD.

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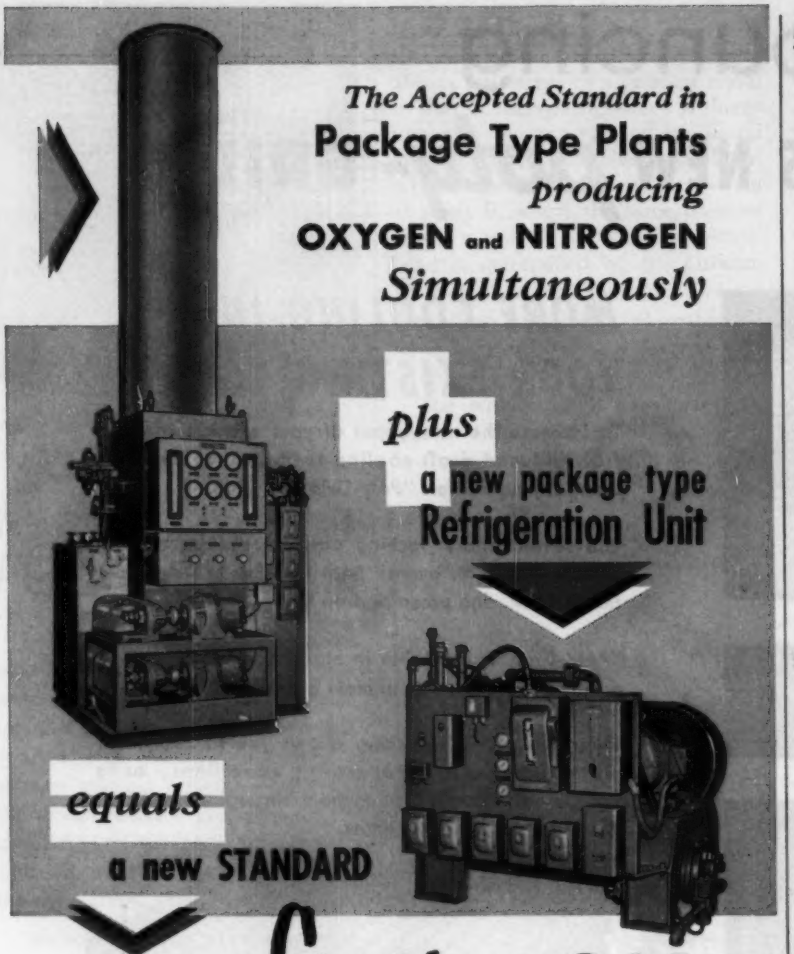
Package Type Plants
producing
OXYGEN and NITROGEN
Simultaneously



now *Liquid* or GAS
OXYGEN and NITROGEN
simultaneously

FLEXIBILITY of operation, providing ANY COMBINATION of products, liquid or high pressure gas PLUS simultaneous production of BOTH oxygen and nitrogen delivers maximum yield of combined products at minimum cost of operation with little operator's attention. Packaged design requires minimum of installation cost and space.

This most modern and efficient design from Independent combines the best features of the earlier two-product package plants pioneered by Independent with the latest concepts of external refrigeration. Type illustrated in 1500 to 5500 cu. ft. per hour capacities. Other types in larger and smaller sizes. Pure argon available on larger sizes.

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CYLINDERS AND GAS PRODUCING EQUIPMENT
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O'FALLON 6, ILLINOIS

How To Do It . . .

(2) 3-inch, 4-hole blind flange
(3) ¼-inch copper tube, 7 feet
(4) 4-inch eight-hole blind flange
(5) two ¼-inch brass mail connectors
(6) 3-inch delivery line to the tank
(7) 4-inch, six-hole blind flange
(8) 150-psi pressure gage
(9) ¾-inch globe valve
(10) ¾-inch steel pipe, 4 feet with 3 ells
(11) safety valve.

The testing device was made using these materials, weighed approximately 10 pounds and was constructed in less than 12 manhours.

Test. Mount the device on the tank as shown in the upper figure. Open the water line gate valves. About 3 to 5 minutes are required to reach 25 psi. Since the pressure rise is moderate, the pressure can be checked at any desired point by closing the gate valves on the water line.

Another advantage to the system, in addition to leak detection, is the ability to check and calibrate the operation of the tank relief valve. Also, manhole leakage can be checked.

The success of this test device encouraged us to make a test stand for safety valves. By adding the following material to the device shown in the upper figure, a safety valve tester was made as shown in the lower figure:

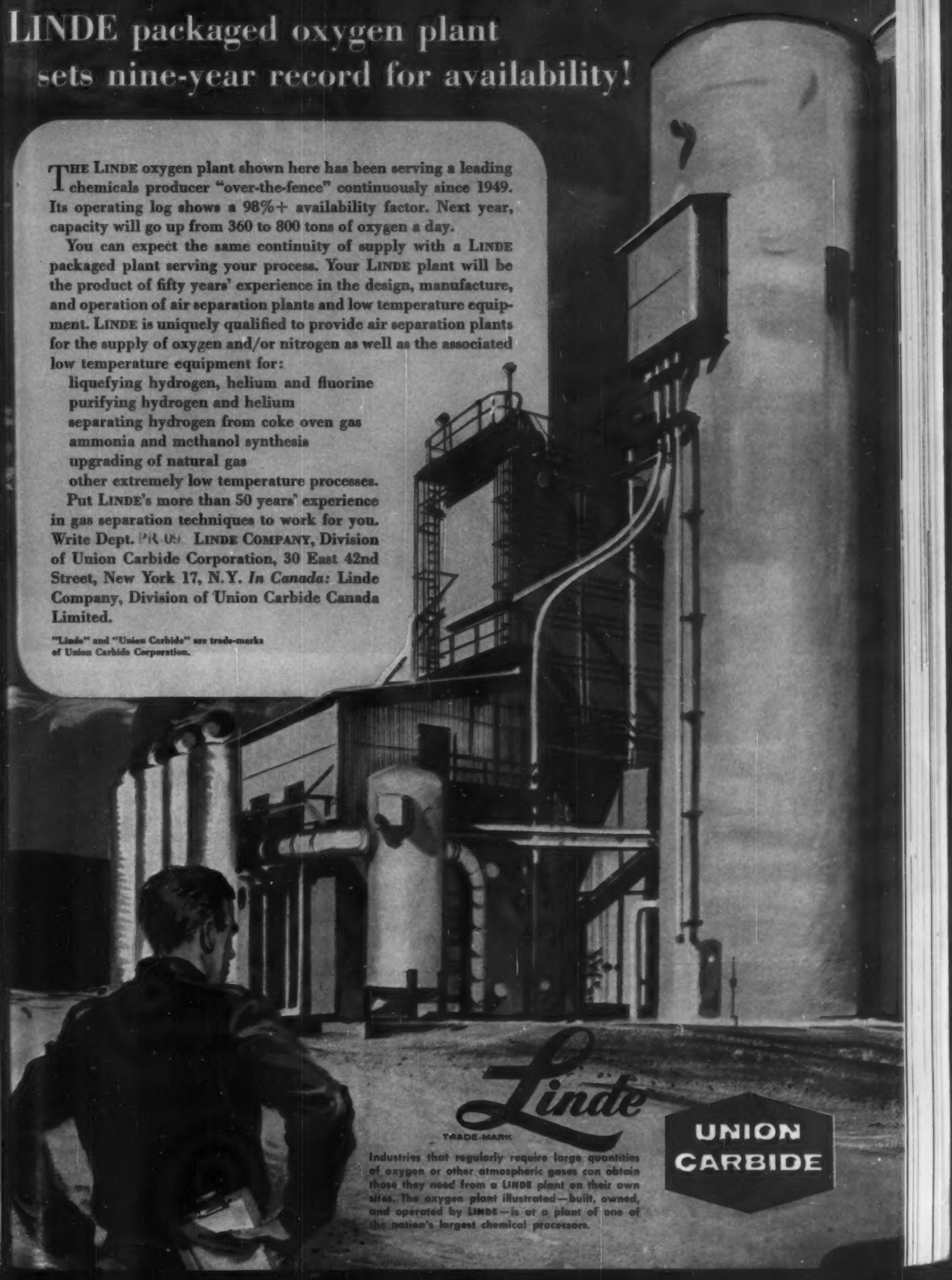
- A ¾-inch diameter by 2-inch long steel pipe coupling, with a ¼-inch brass male connector on one end, is screwed into the globe valve.
- A safety-valve fastening rack consisting of a 3 x 3-inch angle 12 inches long, a 1-inch x 15-inch steel pipe, a ½-inch diameter x 10-inch steel pipe and two ⅝-inch nuts.

The safety valve is mounted on the rack as shown in the lower figure. The main water line is opened—then the ¾-inch globe valve is opened slightly. The pressure will rise to 25 psi within 30 seconds. The valve is

YOUR IDEAS ARE VALUABLE!

At least $10 will be paid for each idea accepted for "How to Do It." Just send a brief note with a photo or sketch to the Editor, *Petroleum Refiner*, P. O. Box 2608, Houston.

LINDE packaged oxygen plant sets nine-year record for availability!



THE LINDE oxygen plant shown here has been serving a leading chemicals producer "over-the-fence" continuously since 1949. Its operating log shows a 98%+ availability factor. Next year, capacity will go up from 360 to 800 tons of oxygen a day.

You can expect the same continuity of supply with a LINDE packaged plant serving your process. Your LINDE plant will be the product of fifty years' experience in the design, manufacture, and operation of air separation plants and low temperature equipment. LINDE is uniquely qualified to provide air separation plants for the supply of oxygen and/or nitrogen as well as the associated low temperature equipment for:

liquefying hydrogen, helium and fluorine
purifying hydrogen and helium
separating hydrogen from coke oven gas
ammonia and methanol synthesis
upgrading of natural gas
other extremely low temperature processes.

Put LINDE's more than 50 years' experience in gas separation techniques to work for you. Write Dept. PR-09, LINDE COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N.Y. *In Canada:* Linde Company, Division of Union Carbide Canada Limited.

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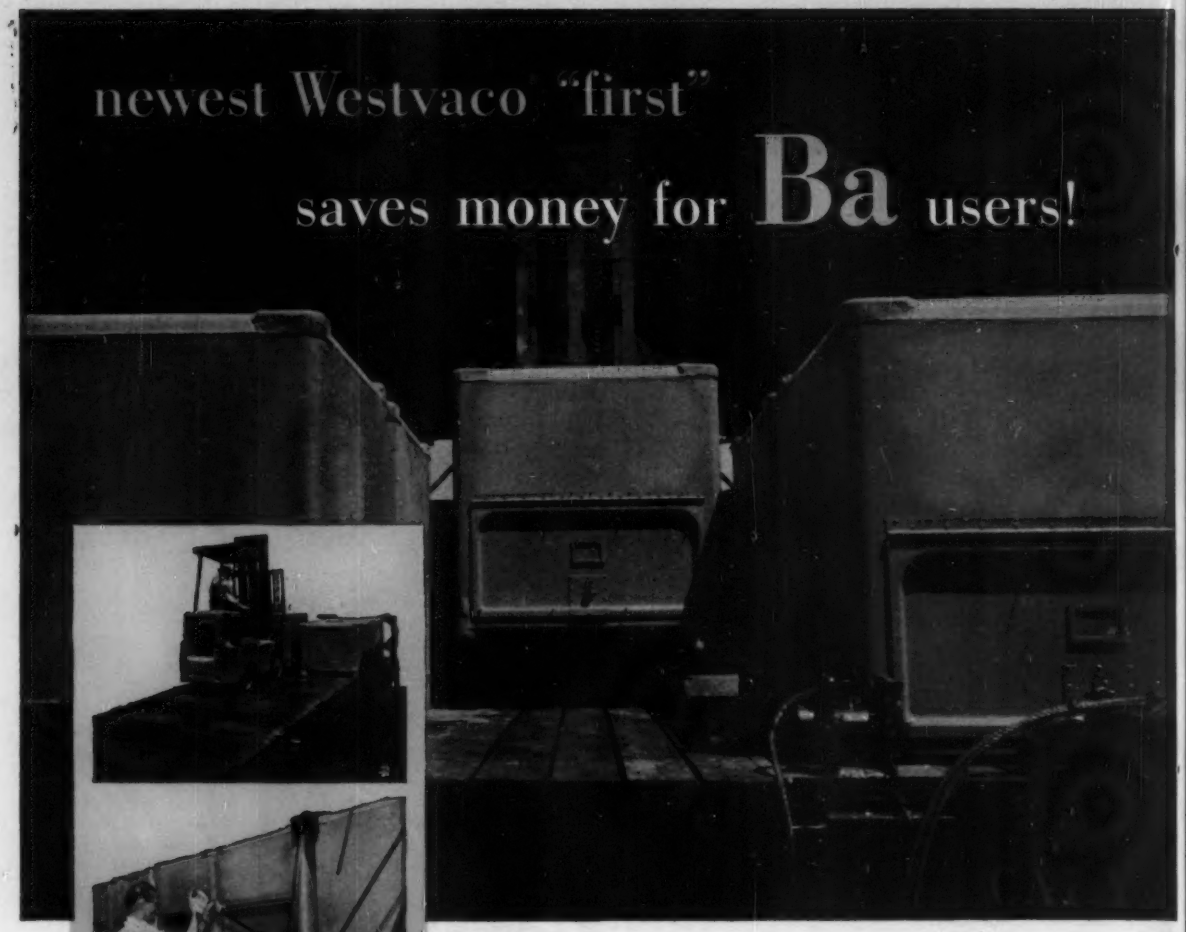
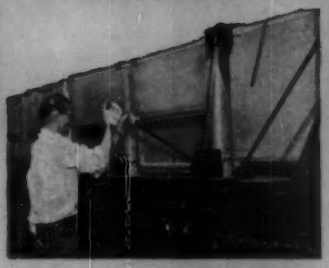
UNION CARBIDE

Industries that regularly require large quantities of oxygen or other atmospheric gases can obtain those they need from a LINDE plant on their own sites. The oxygen plant illustrated—built, owned, and operated by LINDE—is at a plant of one of the nation's largest chemical processors.

newest Westvaco "first" saves money for Ba users!





Illustrations show 5,000 lb. capacity bins being loaded on flat car. Bins have feet which fit in slots to hold them securely in place. When car is fully loaded, cables are tightened and it's ready to roll.

Like many other Westvaco customers, you might be able to realize substantial savings on barium chemicals in these easy-handling, moisture-tight shipping and storage bins. Your nearest Westvaco office will gladly assist in estimating the possible economies in terms of your specific operation.

This modern, money-saving package is the most recent in a series of customer-minded product and service innovations in Westvaco Barium that result from our years of experience.

Through the years we have cooperated with lube oil and other barium users to pioneer new products best suited to their needs. As a result, we offer the widest range of barium products made, backed by fully integrated production and an unmatched record of dependability.

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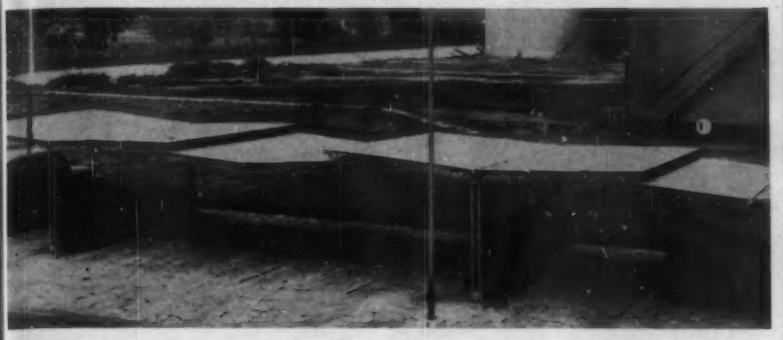
calibrated according to standard procedures.

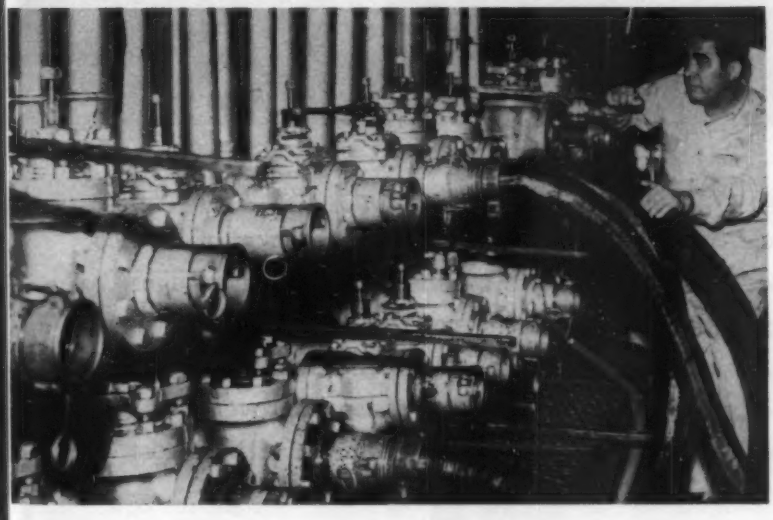
These devices are simple but are also practical and dependable.

This idea was submitted by Chiang Chi-An, Chinese Petroleum Corp., Kaohsiung, Taiwan.



Carport Has Wide Span, Minimum Support

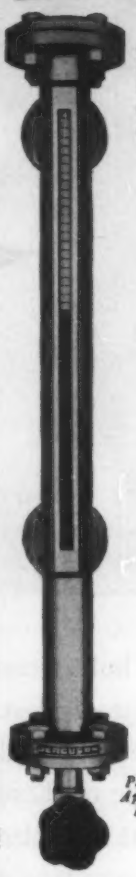
At Pemex's Salamanca refinery, a simple means of providing protection for the company cars was devised by installing a roof between the edges of two roof trusses so that three cars can be parked between the supports. The trusses were swung over the supports in the usual manner for two car protection. Another span was then hung between the conventional trusses, as shown in the photo. A gutter of used boiler flue material was made by splitting the boiler flues and running them down the centers of the spans. This provided a joint in the span as well as a gutter. By making the swinging joints at the high points in the spans, no gutters were necessary. Flagstone was used in the stalls instead of concrete. Result—the entire parking area became a work of art.



Connections Prevent Errors in Blending

One refinery uses hoses instead of three-way valves for blending and for pumping from various tanks to tank cars. By using the hose connections, there is no question as to which tank is being emptied and to which line the discharge from the pump is connected. In the view shown, three basic ingredients and two additives are being blended and run to a certain tank in

Announcing
the New
Jerguson
MAGNETIC GAGE
For Liquid Levels



An important advancement in liquid level observation for plants with dangerous explosive or inflammable conditions.

Safety design seals against escaping gases.

Measuring mechanism in stainless steel chamber.

Scale mounted outside chamber; magnetically actuated through chamber wall.

Distinct, accurate level shown in red contrasted with silver above.

Job designed, correlating pressure, temperature, and specific gravity.

Available with electric alarms.

Patent Applied For

Can also be used for interface indication.

Write now for engineering sheet on Jerguson Magnetic Gages.

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Gages and Valves for the Observation of Liquids and Levels
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REFINERS CHOOSE

Effluent Refrigerated

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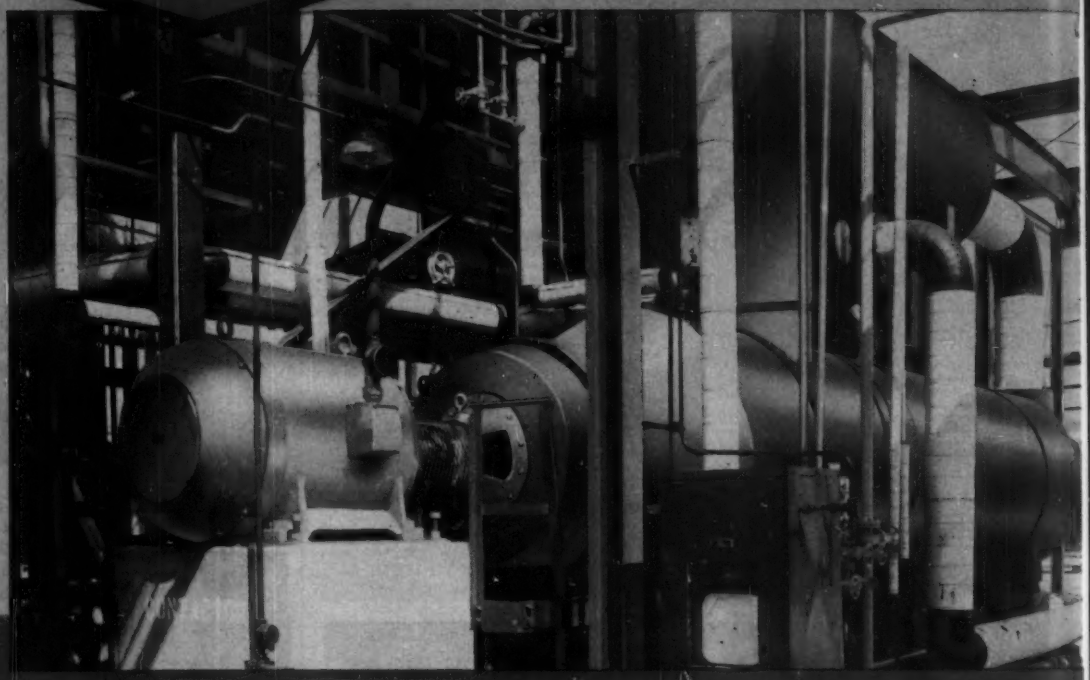

With the Lowest Acid Consumption Record in the Industry

Recently built Stratco units have established the lowest acid consumption records in the industry. Another characteristic of these new plants is a significant reduction, or in many instances complete elimination, of fractionating column reboiler fouling.

Highest quality alkylate and easiest mechanical operation of Stratco installations are other advantages.

Electronically computed flow diagrams and material balances incorporating these improvements are available quickly and without cost.

Representatives
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D. D. Foster Co., So. Charleston, W. Va.
Lester Oberholtz, Los Angeles
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We cooperate with your contractor in plant design.

STRATFORD ENGINEERING Corporation
PETROLEUM REFINING ENGINEERS

How To Do It . . .

the battery. The suction hoses are connected to the proper storage tanks for the ingredients, and the discharge connected to the proper blend tank. When the measured quantities are removed from the stock tanks, there is no doubt as to how much of each is blended into the finished product for sale. When the work is completed, the hoses are disconnected and each exposed valve can easily be checked for leakage.

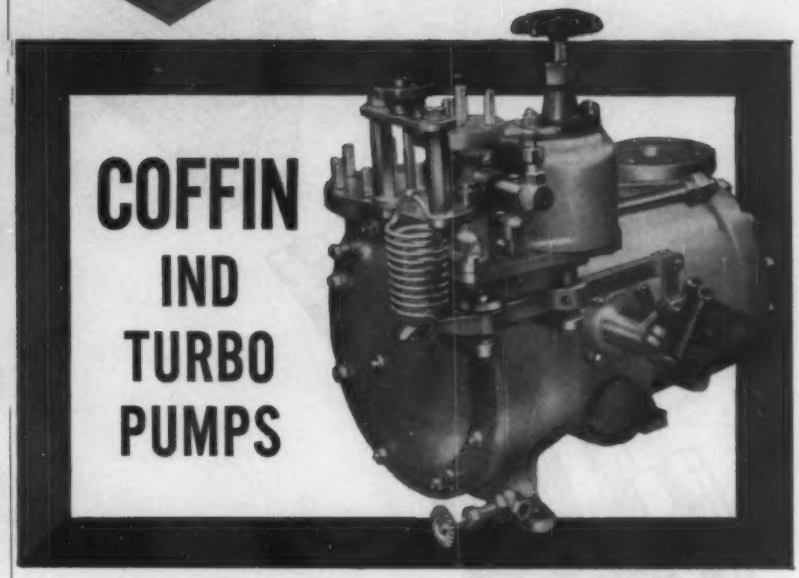
Test Stand Safety-Checks Those Chain Hoists, Cables

This testing stand leaves no guesswork concerning the safety of chain hoists, chokers and other similar apparatus. The mechanic in the photograph is testing both the chain fall and cable to see if they will stand their rated capacities. Note that the panel behind the mechanic is normally closed for greater safety; it is down only for picture purposes.

This idea was submitted by E. N. Smith, The Ethyl Corp., Pasadena, Texas.

Use Reader's Service Postcard on page 486 for more information on advertised products

Complete Pump, Turbine and Controls



PACKAGED — integral design of the IND Pump results in a compact, highly efficient unit which mounts impeller and turbine wheel on a short, rigid shaft. The unit is equipped with complete controls for constant or differential pressure regulation.

APPLICATIONS — compact and highly efficient, the Coffin type IND Steam Turbo Pump is designed for General Boiler Feed or any other pumping service where medium volume and high pressure is required.

SPECIFICATIONS-

Capacities	to 180 GPM	Height 32"
Discharge Pressures	to 350 PSIG	Width 25"
Liquid Temperatures	to 300°F	Length 32"

For special installations these ratings may be exceeded.

Coffin Turbo Pump Co.
326 South Dean Street, Englewood, N. J.
Gentlemen: Please send me illustrated booklet further describing the Type "IND" Pump.

Name _____
Position _____
Company _____
Street _____
City _____ Zone ____ State _____

COFFIN TURBO PUMP CO.
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YARDSTICKS FOR GASKET PERFORMANCE

The No. 1 reason for specifying Flexitallic Spiral-Wound Gaskets is predictable performance. The compression characteristics of each Flexitallic Gasket are always related to the pressure/temperature ratings of the flange. They are made for each other.

But, beyond this, engineers know that Flexitallic Spiral-Wound Gaskets give important advantages such as:

- Wet or dry, there is no change in the compression characteristics of a Flexitallic Spiral-Wound Gasket.
- In Style CG Flexitallic Gaskets, the standard ring completely seals the flange with steel, and gives positive indication of effective bolt load.
- The Flexitallic Spiral-Wound construction gives the safest possible seal for flammable or toxic fluids.

Flexitallic Blue, the blue-dyed Canadian asbestos filler, identifies the original Spiral-Wound Gasket construction.

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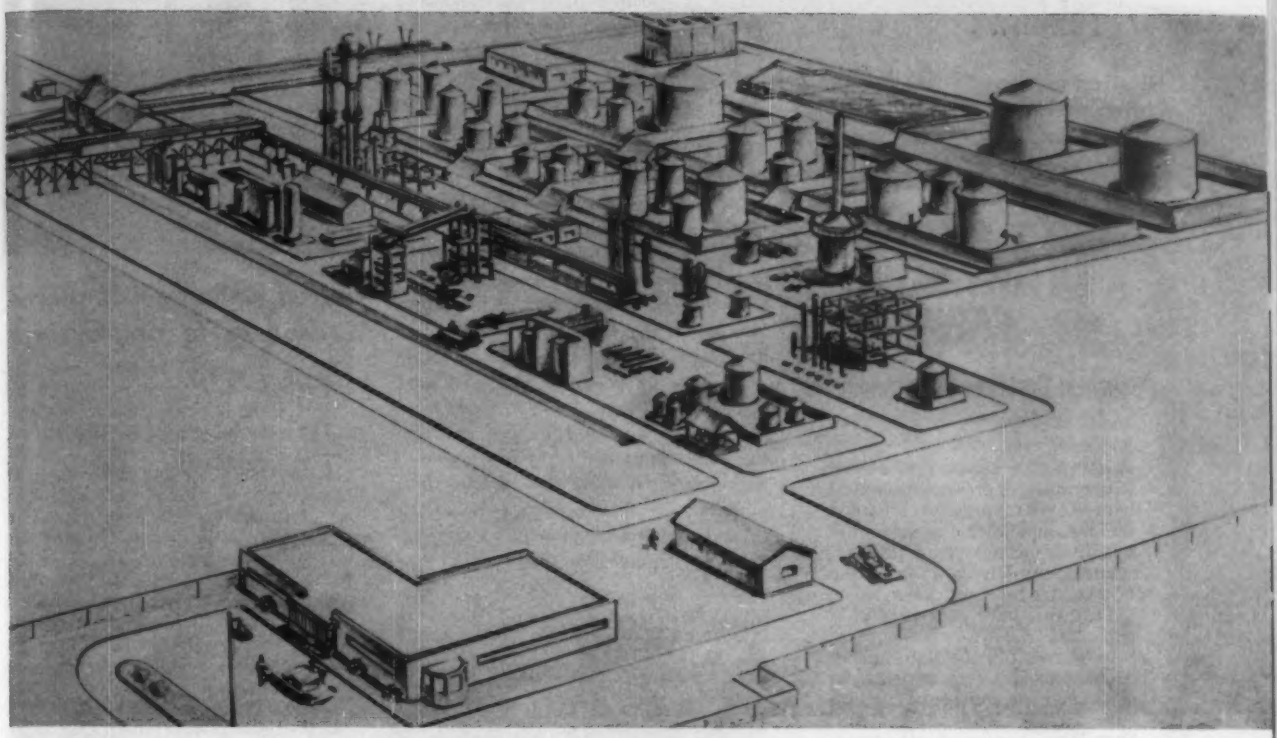
SPIRAL-WOUND GASKETS

FOR PIPE FLANGES, PRESSURE VESSELS AND PROCESS EQUIPMENT

*Flexitallic is a registered tradename. No one else can make a Flexitallic Gasket. Look for *Flexitallic Blue* — it's our exclusive blue-dyed Canadian asbestos filler.

Who's Building...



Continental Oil's new Lake Charles plant will produce 50 million pounds per year of petroleum-derived industrial alcohols.

More Straight-Chain Alcohols Ahead

Conoco has its eye on high-molecular-weight oxo alcohols formerly derived from natural sources

CONTINENTAL OIL CO. plans to construct a multi-million dollar petrochemical plant at Lake Charles for manufacturing from petroleum a line of industrial alcohols formerly produced only from natural oils and fats. The Conoco plant, said to be the first of its type in the world, will have a capacity of more than 50 million pounds annually of straight-chain primary alcohols, for use in the manufacture of detergents, plasticizers, cosmetics, lubricating oil additives, paper, textiles and emulsifiers.

The unique facility will be constructed adjacent to Conoco's refinery at Lake Charles. The Lummus Company, Houston, has been selected to build the plant.

Construction work is expected to start immediately, with completion scheduled for early in 1961. When completed, the plant will employ approximately 125 persons.

At present, petroleum is a basic source of many branched-chain alcohols and low molecular weight straight-chain alcohols. But the higher molecular weight straight-chain alcohols have been dependent on natural sources, such coconut oil and tallow fat.

Products made from straight-chain alcohols have superior use properties that are well known. For example, phthalate esters of straight-chain alcohols have better low temperature and permanence characteristics when used as vinyl plasticizers. And sulfates of straight-chain alcohols are used in synthetic detergent formulations. The Conoco alcohols contain

SERV-RITE®

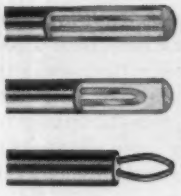
Premium Sheathed Thermocouples

(.020" to .500" O.D.)

Problems of space limitation, temperature, or pressure are solved with SERV-RITE *premium* sheathed thermocouple wire. For maximum sensitivity, accuracy and quick response, SERV-RITE will furnish the best service for your dollar.

Featuring hard-pack insulation with heavy wall construction, SERV-RITE is fully flexible and can be bent to suit requirements. In addition to a choice of junction tips, fittings and connectors, SERV-RITE *premium* sheathed wire is available in a wide range of sheath materials, bright annealed. Standard and special thermocouples are made to suit any need.

All wires used in SERV-RITE *premium* sheathed thermocouple wire are selected and matched to conform to "Special" limits of error as set forth by I.S.A. Recommended Practice, R.P. 1.3. This wire meets the strictest over-all specifications.



Ask for BULLETIN 1200-4

for complete details, ordering data, and prices on SERV-RITE *premium* sheathed thermocouple wires and accessories.

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Building . . .

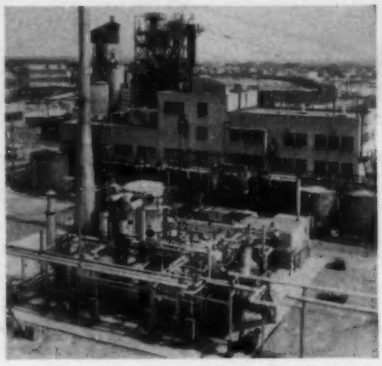
even numbers of carbon atoms from six through eighteen.

Primary raw material for the new products is petroleum-derived ethylene, which Conoco will obtain from the ethylene plant operated at Lake Charles by Petroleum Chemicals, Inc. Conoco owns a 50 percent interest in Petroleum Chemicals.

Development of the new process was announced by Conoco in September, 1958. At that time, the location and size of the plant was undecided.

The facility is being designed on the basis of processing data developed by Conoco's research scientists and engineers at Ponca City, Okla., over a period of five years. The process is based on earlier work done by Professor Karl Ziegler.

Conoco is licensed under the Ziegler patents. In addition, further processes have been developed by Conoco since initiating research work. Basic intermediate produced in the process is aluminum triethyl, a pyrophoric material also utilized in jet propulsion.

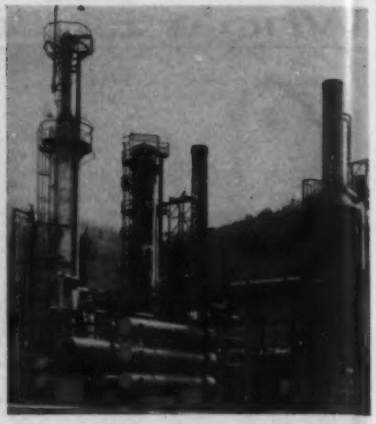


New Sulfur Recovery Plant For Mobil at Paulsboro

Engineering and construction has been completed on a new 100-short-ton-per-day sulfur recovery plant at the Paulsboro, N. J., refinery of Mobil Oil Co. Completed ahead of the scheduled completion date, the plant was designed for economy of operation, with an operating flexibility range of from 21 to 100 percent capacity.

Pure-grade sulfur is obtained from processing sour refinery gases, and the product is shipped in the molten state for a variety of industrial uses.

The plant has aided the refinery's air pollution abatement program. A gas chromatograph is used to analyze recoverable sulfur present in the tail gases, which are discharged into the atmosphere.



United Refining Completes Hydrogen Treating System

A new hydrogen treating system recently placed on stream by United Refining Co., is the latest step in the company's modernization of its Warren, Pa., refinery.

The system, according to the designer, Blaw-Knox Co., Chemical Plants Division, Pittsburgh, will upgrade virgin naphtha used as feed stock for reforming into high-octane gasoline. The upgrading consists of removing the compounds of sulfur, arsenic and nitrogen, contaminants highly deleterious to reformer catalyst life. The system selected by United Refining to improve naphtha is applicable to a wide range of petroleum products.

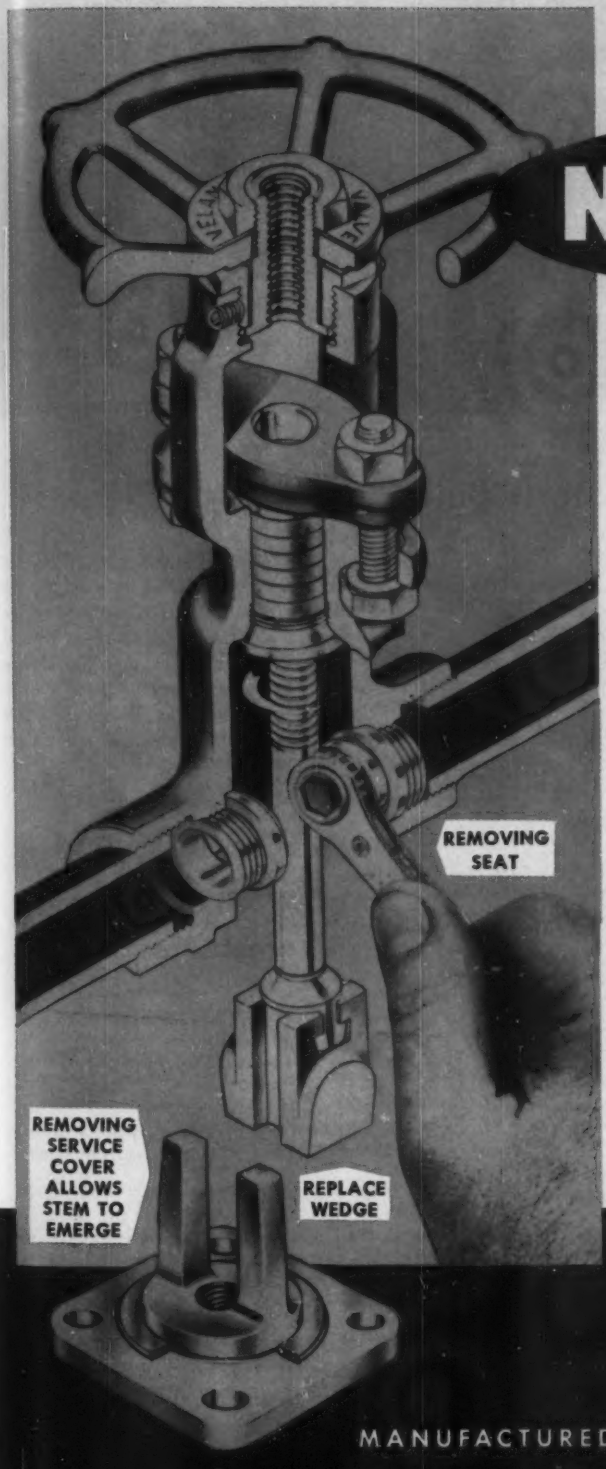
Installation of the Unifiner, together with modifications to the catalytic reformer, have upper United Refining's output of high octane gasoline.

Humble Oil & Refining Co. has completed its new phenol plant No. 2, Baytown refinery. The 31,000-bpd unit will remove undesirable components in catalytic recycle streams by means of phenol extraction.

Phenol No. 2 is the first major unit built entirely by Humble forces in several years. Principal equipment includes four towers, several air-cooled exchangers, and a modern control house. A novel feature of the unit's processing equipment is the use of centrifugal extractors instead of conventional gravity-type separation towers. The new-type extractors will save space and substantially reduce the phenol required.

Great Northern Oil Co. is constructing a sulfuric acid alkylation plant with an LPG bonus at its Pine Bend, Minn., refinery. Initial production of the unit will be 1,500-2,000 bpd, with ultimate capacity set at about 3,800 bpd. Construction is scheduled to start in October, with completion due in Summer, 1960. The Refinery Engineering Co. is handling process and mechanical design, and all engineering and construction.

Design of the unit makes a single processing step of feed preparation and depropanizing operations, and eliminates



INTRODUCING THE

NEW VELAN

BONNETLESS
FORGED STEEL
GATE VALVE

1. Velan Valves will stay in the line at least twice as long as standard gate valves under same operating conditions. The valve does the work of 2 valves and provides double-block bleed.
2. Only Velan Valves can be readily tested for tightness of both seats and are guaranteed for impenetrable tightness from both sides.
3. Drop forged one-piece bonnetless design eliminates conventional body bonnet gasket leakage and assures perfect alignment of all working parts.
4. Only Velan Valves can be cleaned or flushed in the line under full pressure or during shut-down resulting in longer valve life and increased production.
5. Only Velan Valves can be tested for tightness in line under full pressure during shut-down.
6. Positive and smooth guiding of wedge with very little clearance eliminates drag and wear on seating faces during closing and opening of valve.
7. Inexpensive guide cover can be replaced to provide new positive guiding of wedge.
8. Valve is not easily damaged due to excessive torque when using extension wrenches.
9. Hardened (or Stellited) ground lapped seats resists better corrosion.
10. Slightly damaged seating faces on seats can be easily relapped in the lines.
11. Easily replaceable screwed-in seats, fully interchangeable for the first time in any Gate valve.
12. Wedge can easily be removed in the line.
13. Positive backseat isolates stuffing box from line pressure and enables repacking under pressure.

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IN U.S.A. AND CANADA BY VELAN VALVE CORP.
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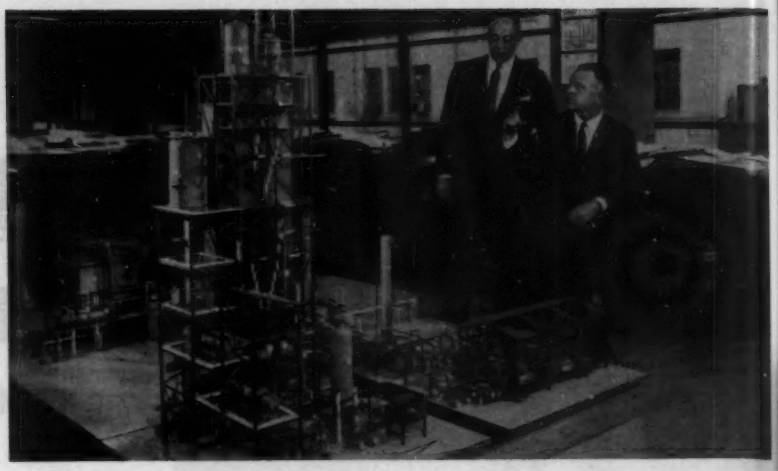
Building . . .

the need for separate debutanizing facilities for control of vapor pressure.

The later process variable is achieved through withdrawal of a vapor side-cut stream from the debutanizing tower. The side-cut stream is fed to a rectifying column, which knocks out the heavier ends, such as isopentane, and returns a high-purity normal butane meeting NGAA specifications. Heavier ends from the rectifier are returned to the DIB column. Treco will also install extensive offsite facilities, including tankage, a cooling tower, and acid and hydrocarbon loading and unloading facilities.

Celanese Corp. of America has completed a multi-million dollar expansion of its acetic acid facility at Pampa, Texas, nearly doubling its capacity, and making it the "largest acetic acid plant in the country." The 240-million-pound-a-year facility will produce both acetic acid and acetaldehyde. The process used consists of partially oxidizing hydrocarbons under high pressure followed by a complex series of purification steps.

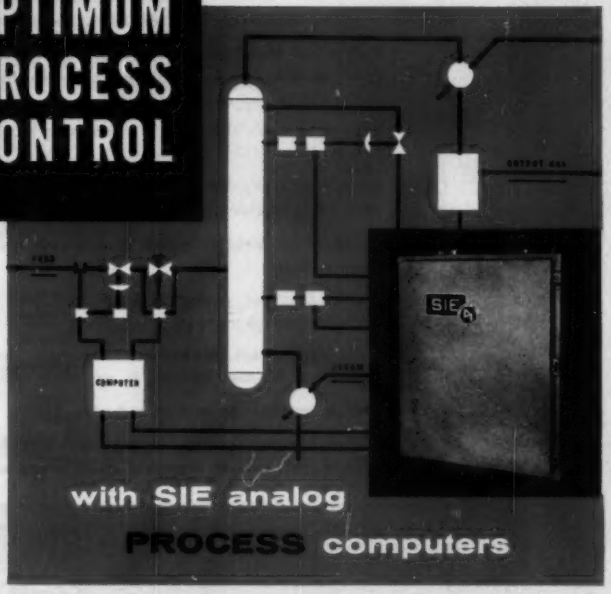
The expansion was planned early in 1958, engineering was completed last Fall, and Brown and Root Construction Co., Houston, began work in December. New facilities, which include high-volume centrifugal compressors, major alterations to purification units and new distillation towers, were completed three months ahead of schedule.



SunOlin Starts Building Big Urea Plant

Construction of the East Coast's first major urea plant, an $8-million venture of Sun Olin Chemical Co., has begun. Scheduled for completion early next spring, the plant will produce 73,000 tons annually, plus 10 MMcf of hydrogen for ammonia production and other refining processes. The plant will use the Montecatini process, in which liquid ammonia and carbon dioxide gas are reacted at 2,800 psi and at 370 F to form ammonium carbamate. This decomposes to urea and water. Sun Olin's plant will be one of the few in the United States that completely converts ammonia and carbon dioxide to urea. It is also one of the few U. S. plants equipped to make both prilled and crystalline urea.

OPTIMUM PROCESS CONTROL



with SIE analog PROCESS computers

no ● moving parts
no ● vacuum tubes
no ● contacts

SIE CM-2 Analog Computers provide precise control in chemical, petrochemical, refining, and similar process applications, to a degree never before possible. Using this new concept, process variables are taken into account in adjusting set-points automatically to achieve optimum output yield.

Using Magnetic Amplifiers and Transistors CM-2 Series Computers have a **trouble-free life expectancy in excess of 100,000 hours,** yet in a typical fractionator application now in operation, computer cost was less than $5000.

Write for Brochure Describing Applications in Feed-Ahead, Feed-Back, and Operator Guidance computations. SIE engineers will welcome the opportunity to discuss the use of CM computers in your specialized process control applications.

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QUESTION:

What "priceless extras" will you find in Worthington high speed turbines?

for answer, turn page ——→

4920 hp, 7000 rpm Worthington turbine driving a centrifugal compressor at Sinclair Refining Co.'s East Chicago, Ind., plant

ANSWER:

A Six quality features . . . key to reliability

Reliability is the ultimate goal of every step that Worthington takes in the design and manufacture of compressor-drive turbines. Worthington reliability is confirmed by 32 years of experience in this specialized field and over 1,257,643 installed horsepower driving all major makes of compressors. When planning your next centrifugal compressor installation, *regardless of compressor manufacture*, be sure to specify a *Worthington* turbine to assure top reliability with flexible, fast and specialized customer services. Worthington Corporation, Wellsville, New York. 48-5

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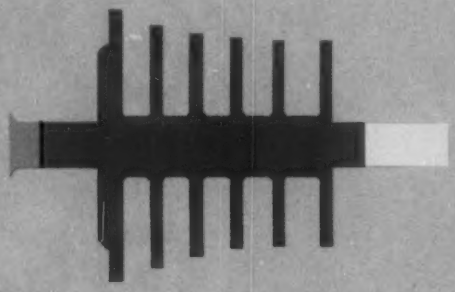
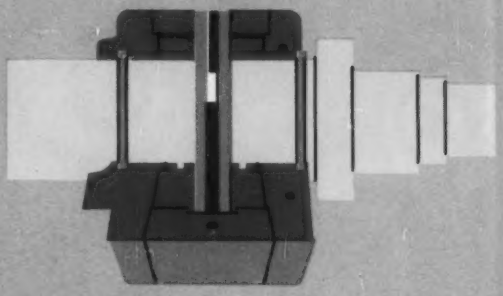
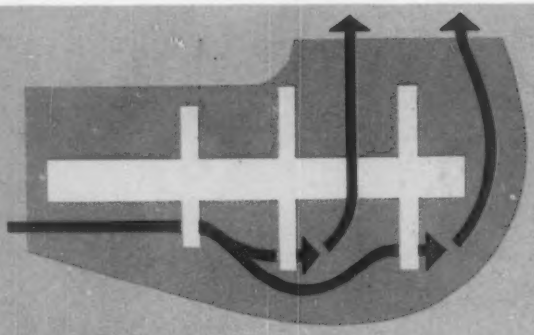


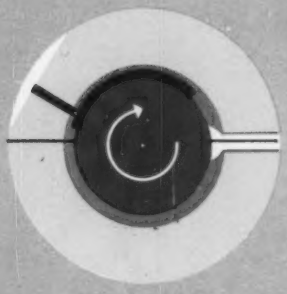
SOLID ROTORS—wheels forged integral with the shaft—provide a more rugged, conservative design.



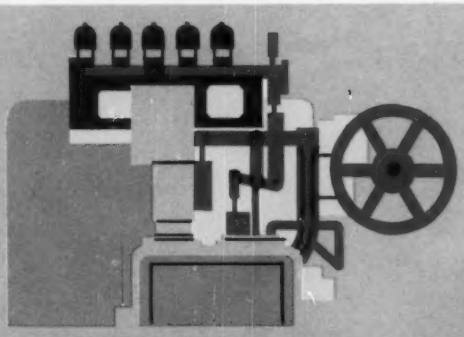
KINGSBURY-TYPE THRUST BEARINGS withstand heavy thrust loads. Shoes pivot, forming a wedge-shaped oil film between thrust collar and bearing surface.



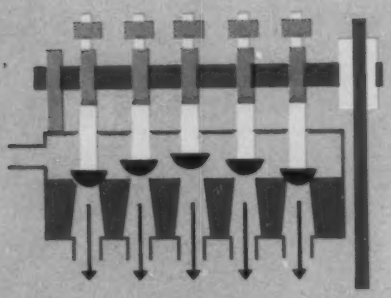
DOUBLE-FLOW EXHAUST—the last stage is divided into two wheels—reduces blade length, increasing efficiency.



ANTI-OIL-WHIP BEARINGS keep vibration to a minimum. An oil dam in upper half of bearing builds up a pressure pad, keeping rotor firmly in place.



SENSITIVE SPEED GOVERNING SYSTEM provides close control over a wide speed range. (Governor takes air impulses from an outside controller to vary speeds.)



CAM-OPERATED AUTOMATIC NOZZLE CONTROL. Each valve, with separate cam, controls a group of nozzles for maximum economy at all loads.

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Building . . .

Industrial Development Corp. of South Africa, Ltd. is planning to build a 22-million-pound-per-year carbon black plant in the Union of South Africa. The project will be a joint venture equally owned with Phillips Petroleum Co. The two firms will form Phillips Carbon Black Co., Ltd., to build and operate the facility, which is slated for 1961 completion.

Goodyear Tire & Rubber Co. will team with Firestone Tire & Rubber Co. and Petrobras to build a synthetic rubber plant next to the 90,000-bpd refinery operated by the Brazilian Government near Rio de Janeiro. The American companies will finance the $6-million, 40,000-ton-per-year project. It is slated for completion late in 1960.

California Texas Oil Co. is planning, along with Standard Vacuum Oil Co., British Petroleum Co., and Royal Dutch Shell, to build a $30-million refinery in Ceylon, in which the Celonese government would have a 20 percent share. Negotiations regarding the plant are in the final stages. The refinery would be built on the island's East coast, about 200 miles from Colombo.

Rumania is building two large ammonium nitrate plants at Fagaras and Roznov. The Fagaras plant, with a 30,000-ton-per-year nitrogen capacity, will be completed early next year. The Roznov plant's capacity will be upped from 62,000 tons per year to 80,000 tons. It will be complete in late 1962 or early 1963. Both plants will use an indigenous natural gas process with a methane content of 99.5-99.8 percent.

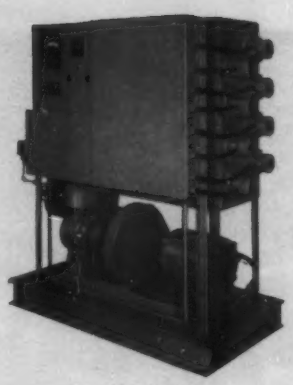
The Dow Chemical Co. has purchased a vacant Findlay, Ohio, industrial plant which it will convert for the manufacture of polyethylene film. The plant, built in 1947 by National Automotive Fibres, Inc., occupies about 208,000 square feet on a 27-acre site.

Dr. Mark E. Putnam, Dow executive vice president, said the facilities will serve film customers in the Midwest and East. Initial employment is expected to be about 100. The Dobeckmun Co. a division of Dow based in Cleveland, will join in production planning and engineering.

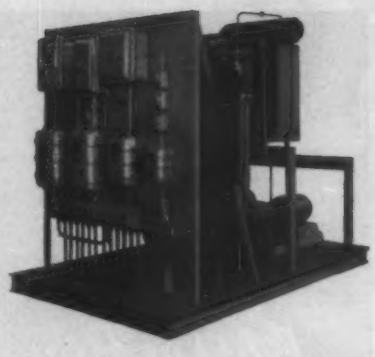
Shell Oil Co. plans to build a new distillate hydrotreater at its Houston refinery. Construction will start soon, and completion is scheduled for the second quarter of 1960. The $2-million unit, which will employ a Shell process will further improve the quality of 30,000 bpd of furnace oil and diesel fuel by removing impurities.

Japanese Geon, Ltd. has completed the first synthetic rubber plant to begin production in Japan, at Kawasaki.

The $1.3 million plant, with a capacity for producing 8,400 tons of rubber a year, is owned by Japanese Geon, an associate company in which The B. F. Goodrich Co. holds an interest, and was designed



Standard Model.



Explosion-Proof Model made in Group 1 Class D Construction.

Model with Heat Exchanger for final product cooling. Note wheels for mobility.

Multiple Heater Model for manual or automatic operation at partial loads.

SIMPLE, SAFE, ECONOMICAL TRANSFER OIL HEATING SYSTEMS

Whitlock Transfer Oil Heating Systems are available for prompt delivery in standardized "packages" which include expansion tank and heating units with operating controls to heat chemically stable transfer oils. Such oils now commercially available, are liquid over considerable temperature ranges, and are being used increasingly in chemical processing operations. The Whitlock units illustrated are complete and require only oil and electrical connections for immediate operation. There's a size and model ready-made for most installations. When required we can make special units to your order.

Since these "packages" handle the oil at low pressures, averaging 15 psi, and temperatures up to 600°F, they eliminate need for high pressure design techniques, thereby simplifying process design and reducing overall equipment cost. Carefully selected controls maintain the oil supply temperature accurately within ±2°F, and the design precludes oil deterioration. Pilot lights on panel indicate system is operating correctly. Write for information and prices.

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For more data on advertised products, use Readers' Service Cards, last page.

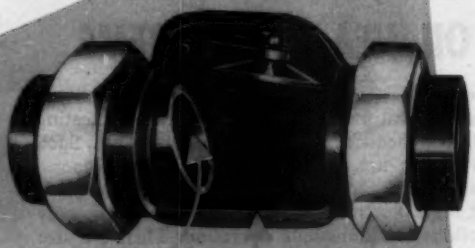
NEW DUCTILE IRON BODY

CATAWISSA "502" CHECK VALVES

1000 psi CWG 3000 psi Test
Sizes: 2" thru 4" N.P.T.

- COMPACT
- EFFICIENT
- ACCESSIBLE
- EASY TO INSTALL
- EASY TO INSPECT

for general flow line and pipeline use . . . horizontal or vertical



Here is one valve designed to take the rough handling necessary in most applications!

Metallographic structure of the ductile iron body resists leakage or seepage of liquids or gases.

FULL OPENING
DUCTILE IRON BODY
ASTM Spec. A-105, Grade 2, Forged Steel Union Ends

In production, pipeline or refinery use—the "502" has earned a reputation for long-life service and satisfaction . . . and now it's a better valve, a better buy than ever!

Catawissa "502" Check Valves withstand severe service conditions with built-in resistance to wear, shock or elevated temperatures. Their resistance to oxidation and a wide variety of corrosive media make them especially valuable where corrosion is a factor. Get the full story on all of their extra-value features!

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and built under the supervision of Goodrich Chemical Co. Division.

The plant is designed so its capacity can be expanded to 15,000 tons a year. It will produce general purpose rubber for tires and industrial products and special purpose rubber for applications requiring resistance to oil, gasoline and chemicals.

The plant, located about 100 miles from Yokohama, is the third manufacturing facility erected by Japanese Geon. The company has vinyl resin production facilities at Kambara and Takoaka.

Aurora Gasoline Co. is building a naphtha Unifining unit to clean up charge stock to an existing Rexformer at its Detroit refinery. The unit, designed for an initial capacity of 8,000 bpd, may be expanded to 12,000 bpd. Refinery Engineering Co., which will handle construction, also designed and is installing a sulfuric acid alkylation unit with an initial capacity of 2,000 bpd. This unit can be expanded to 3,700 bpd.

Amoco Chemicals Corp. has started construction of a semi-commercial plant to produce trimellitic anhydride, just south of Joliet, Ill. The company says this is the first stage in Amoco's plans for full-scale commercialization of trimellitic anhydride. The plant is slated for completion by mid-1960, and pilot plant quantities of other new aromatic acids will be introduced during the next year.

Goodyear Tyre & Rubber Co. (Australia) Ltd. has acquired a substantial interest in a new synthetic rubber plant being built by Australia Synthetic Rubber Co. Ltd. Located at Altona, near Melbourne, the $11-million plant will have a yearly capacity of 30,000 long tons of styrene-butadiene rubber, and is scheduled for completion in July, 1961. The new synthetic installation is part of the Australian Commonwealth's $50-million petrochemical project being built by Vacuum Oil Co., Pty., Ltd.

Kuwait Oil Co. has begun operating a new Platforming unit at its Minaal Ahmadi refinery. British Petroleum Co. and Gulf Oil Corp. each have a 50 percent interest. The Platformer can process 4,000 bpd of charge stock (a naphtha fraction prepared from straight-run gasoline derived from Kuwait crude oil), desulfurizing and upgrading it to produce a high octane platformate. This is blended with other gasolines produced in the refinery to yield a premium grade motor gasoline.

Stauffer Chemical Co.'s LeMoyne, Ala., plant is adding a new type of methane purification plant that will be completely automatic and unattended. It will separate propane and heavier hydrocarbons from a pipeline gas stream to produce a relatively pure methane stream with a daily capacity of several MMcf. The plant was built by The Refinery Engineering Co. Using an unusual low-

Photographed at Gulf Refinery, Philadelphia, Pa.

THE GOLDEN RULE THAT PRODUCES RESULTS...

Our golden rule is teamwork between refiners and Cyanamid. As a result of this teamwork, Cyanamid produced the first fully regenerative platinum reforming catalyst and helped develop the first micro-spheroidal synthetic fluid cracking catalyst. Continued co-operation between refiners and Cyanamid is sure to produce further advances in catalytic refining techniques.

Symbolizing this co-operation is Cyanamid's salesman–the man with the golden rule. You can depend on him at all times for help in meeting the operating problems caused by demands for ever-improved fuels. His personal knowledge is backed by the research and production facilities of one of the world's leading producers of catalysts. Call him anytime he can be of help to you . . .

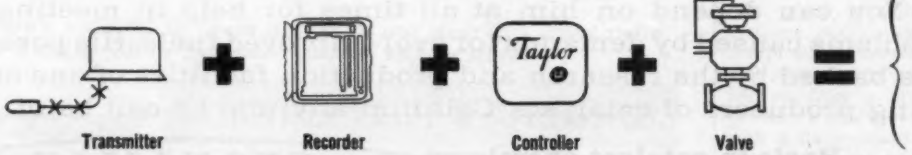
Basic in catalyst chemistry CYANAMID

AMERICAN CYANAMID COMPANY • REFINERY CHEMICALS DEPARTMENT • 30 Rockefeller Plaza, N.Y. 20, N.Y.

The best Control System is the one ***Taylored*** *to your Control Problem*

INSTRUMENT SOCIETY OF AMERICA

PNEUMATIC SYSTEMS



475 years of Cumulated Experience will be at Your Service in Taylor Booths 444 and 545 at the ISA Show

WHETHER you are interested in a complete control system, or in one of our new developments, the team of top Taylormen listed here will be at the ISA Show in Chicago to consult with you.

Drawn from our Application Engineering, Design Engineering, and Sales Departments, these men have behind them many years of experience in instrumentation throughout the processing industries. They are responsible for the enviable reputation that Taylor is earning around the world . . . a reputation for vision and ingenuity in working out successful solutions to tricky control problems.

You will see the most advanced models in both pneumatic and electronic instrumentation on display. Many of them will be demonstrated as working models.

Here is an opportunity to tap a storehouse of information on all aspects of process control. Consultation with these men will cost you nothing—it may save you much.

• • •

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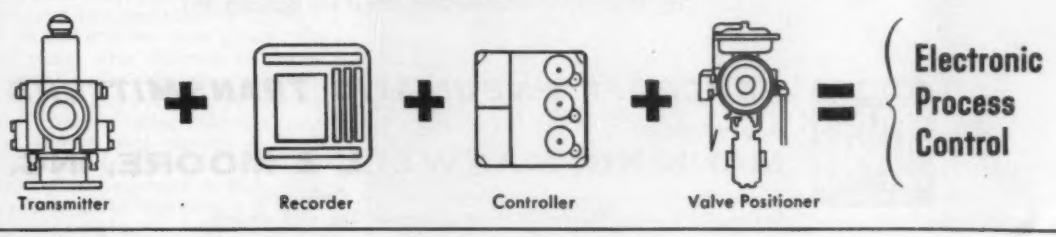

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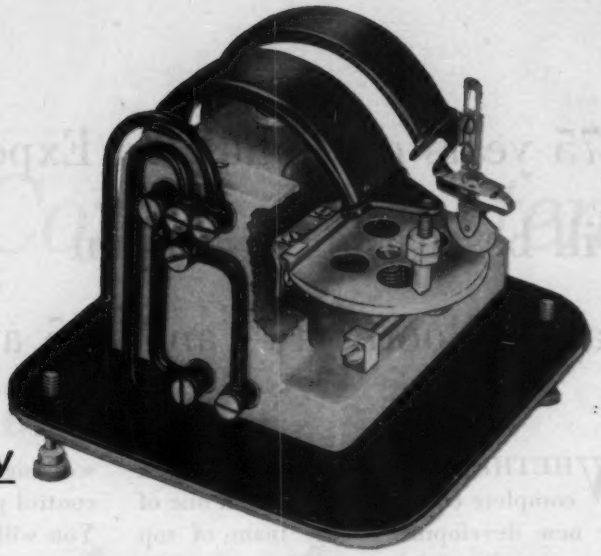


NEW
high sensitivity
ASHCROFT
PNEUMATIC TRANSMITTERS
lower costs...reduce maintenance ...provide tighter control

Ashcroft Non-Indicating Pneumatic Transmitters are made in pressure and temperature types, each in regular and short span. Operation is on low-pressure air: output range, 3-15 psi or 3-27 psi.

These new transmitters are designed around (1) a powerful, efficient relay with sensitivity high enough to operate controllers, and (2) a simple, dual Bourdon tube motion-balance system. High sensitivity permits the use of narrowest proportional band settings on controllers and allows instant controller response to deviations from set point. With a shorter transmission lag, automatic corrective action starts before the deviation becomes critical.

In manual control systems, these new Ashcroft Transmitters (teamed with suitable receivers) make it practical to operate boilers at the most efficient level. In wet processing operations, fractionating columns yield a purer product. Highly suppressed Ashcroft Short Span Transmitters are so sensitive they can "judge" entire control loops and detect any errors in the system.

Basically a 6" cube, lighter than most 8½" pressure gauges, these climate-proof Ashcroft Transmitters are simple to install in cramped locations, are most readily accessible for adjusting or service. Calibration is extremely easy, with linearity checking entirely eliminated. Most parts in all types in the line are interchangeable. Ask your nearby Ashcroft Gauge Distributor about the lower initial costs and other savings that follow when you install Ashcroft Non-Indicating Pneumatic Transmitters. Send for Bulletin 361.

MANNING MAXWELL & MOORE INC. MM&M TRADE MARK

ASHCROFT PNEUMATIC TRANSMITTERS

A product of

MANNING, MAXWELL & MOORE, INC.

Consolidated Ashcroft Hancock Division • Stratford, Connecticut
In Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario

Building . . .

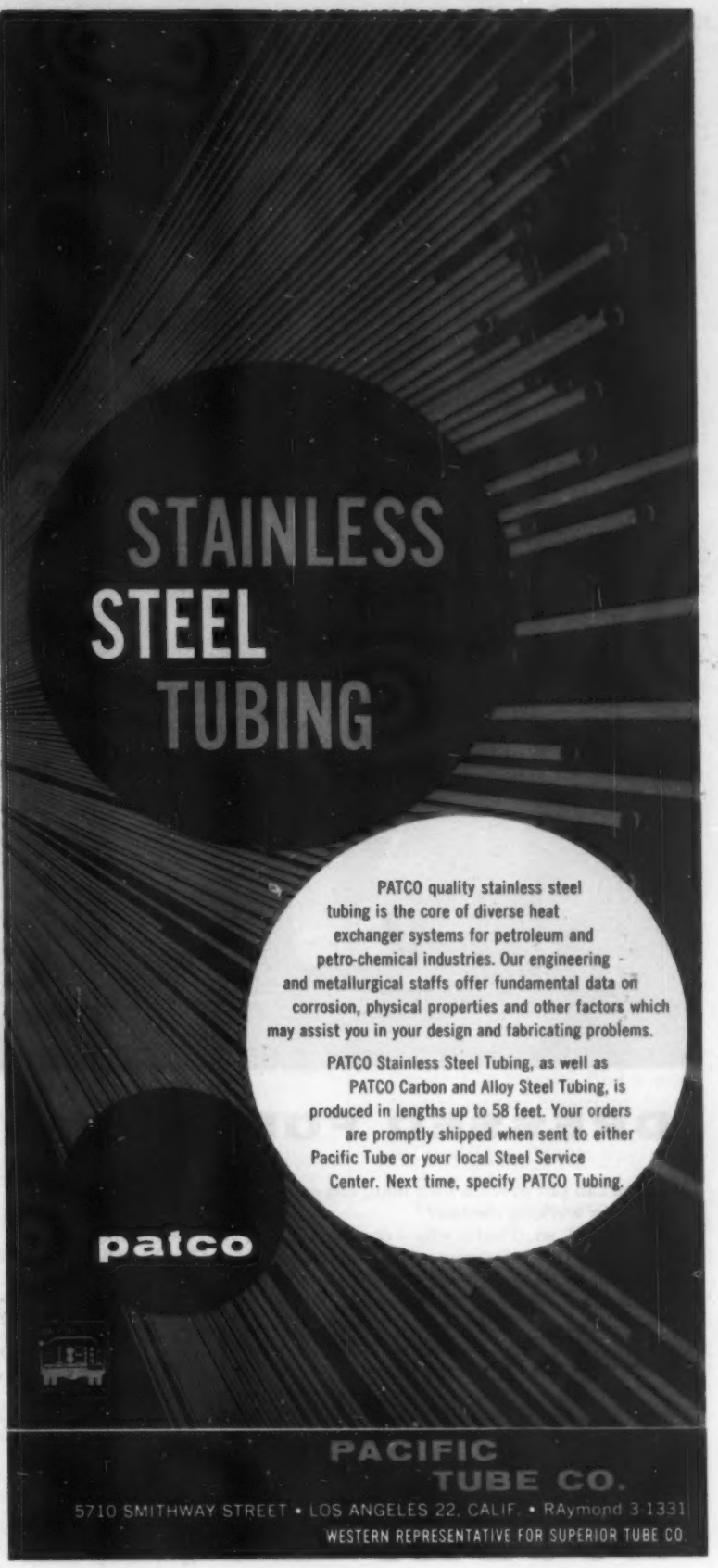
temperature absorption process and low-molecular-weight lean oil, projected plant size was reduced to allow skid-mounting. The entire plant will be erected on skids in Tulsa and shipped intact, except for two towers, to LeMoyne. The towers will be installed in Tulsa and knocked down for shipment.

Bureau of Mines is about to begin operation of the Nation's newest helium plant, under construction at Keyes, Okla., since last November. Designed to produce 290 MMcf of helium a year, the plant is expected to reach full-scale production soon. Its output, added to that of four other helium plants now operated by the Bureau of Mines, would bring the government's total annual helium production to about 600 MMcf. The new plant, which will process natural gas from Cimarron County, Okla., reflects latest technical improvements in helium-extraction methods leading to 99.995 percent pure helium. The Fluor Corp. built the Keyes plant under an $8.9-million contract. In all, the installation will represent a total investment of approximately $12 million, which includes the site and certain plant additions arranged separately by the Bureau of Mines.

E. I. duPont de Nemours & Co. plans to build a major polyethylene resin plant at its Victoria, Texas, works. Construction by the company's Engineering Department will begin soon and is expected to be completed by early 1961. The new unit will be DuPont's second polyetheylene plant. The Sabine River Works, Orange, Texas, will continue as the company's major facility for polyethylene. A major expansion, which almost doubled capacity of Sabine River Works for manufacturing polyethylene resin, was completed last year. Since its completion in 1951, the Victoria plant has produced adiponitrile.

California Chemical Co. plans to build the West's first chemical maleic anhydride plant. The multi-million dollar unit will have a capacity of 20 million pounds annually, and will be built at Standard Oil Co. of Calif.'s refinery at Richmond, Calif. Scheduled for completion by mid-1960, the plant's marketing will be carried on by California Chemical's subsidiary, Oronite Chemical Co. Feed stock for the new installation will be benzine, which the company produces.

Mitsui Petrochemical Industries, Ltd., Iwakuni City, Japan, is completing expansions of its terephthalic acid, ethylene glycol and ethylene oxide plants. The original plants were designed by Scientific Design Co., Inc. Mitsui's terephthalic acid plant, the first operating plant using Amoco Chemicals' xylene oxidation process, has doubled total capacity to about 30 million pounds per year. The original plant was placed onstream in Fall, 1958, and has been in full operation ever since. The ethylene glycol plant, completed


STAINLESS
STEEL
TUBING
PATCO quality stainless steel tubing is the core of diverse heat exchanger systems for petroleum and petro-chemical industries. Our engineering and metallurgical staffs offer fundamental data on corrosion, physical properties and other factors which may assist you in your design and fabricating problems.
PATCO Stainless Steel Tubing, as well as PATCO Carbon and Alloy Steel Tubing, is produced in lengths up to 58 feet. Your orders are promptly shipped when sent to either Pacific Tube or your local Steel Service Center. Next time, specify PATCO Tubing.
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DRESSED FOR WORK!

You can put overalls on a man, but can you expect a man's thoughts to "wear working clothes?"

We think so. That's why—once you tell us your requirements for a process such as reforming—you can expect us to show up ready to *work*.

You can also expect new ideas. And with them comes wide experience in catalysts, catalyst research, pilot plants and all grades of charge stocks. This is your assurance of results—top efficiency from the Houdriforming or Iso-Plus Houdriforming process best for producing high octane gasoline or aromatics from your raw materials.

Our "shirtsleeve-kind of service" continues—to help you maintain peak efficiency—*after* the process goes on stream. Mentally and physically, we *stay* dressed for work as long as we're serving you.

*HOUDRY

PROCESS CORPORATION

1528 Walnut Street, Philadelphia 2, Penna.

*Houdry means Progress...through Catalysis

Building . . .

more than a year ago, has doubled capacity to about 20 million pounds per year.

Currently underway is expansion of Mitsui's year-old ethylene oxide plant which uses the direct air oxidation process. When completed by the end of this year, the expanded plant will have a capacity of about 26 million pounds of high-purity ethylene oxide per year.

Fiber Industries, Inc. has been granted a license to produce and market a polyester fiber in the United States by E. I. duPont de Nemours & Co., Inc. The company expects to be marketing fiber by the middle of 1960. It will be produced in a plant under construction in Shelby, N. C., in both staple and filament forms, for uses in apparel and home furnishings. It will be marketed by Celanese Corp. of America.

Pittsburgh Coke & Chemical Corp. has named The Fluor Corp., Ltd., to perform construction in expansion of an activated carbon plant at Neville Island, Pa. Installed will be new production equipment as well as alteration and modification of existing facilities. New truck and rail loading docks and a new warehouse building will be added. Completion of the new unit is scheduled for November 1. The plant process was developed by Pitsburgh Coke to produce activated carbon. Singmaster & Breyer, Inc., will handle mechanical design for the $800,000 plant addition.

Southwestern Nitrochemical Co. plans to build a $4-million ammonia plant in Chandler, Ariz. The 80-ton-per-year-plant is slated for completion in January, 1960. Southwestern Nitrochemical is a subsidiary of Southwestern Agrochemical Co. and First Mississippi Corp., and currently produces sulfuric acid and ammonium phosphate.

The American Oil Co. has put two new pipe stills on stream at its Texas City refinery. Together, they will add about 18,000 bpd of capacity to the plant, bringing the total to 55,000 bpd.

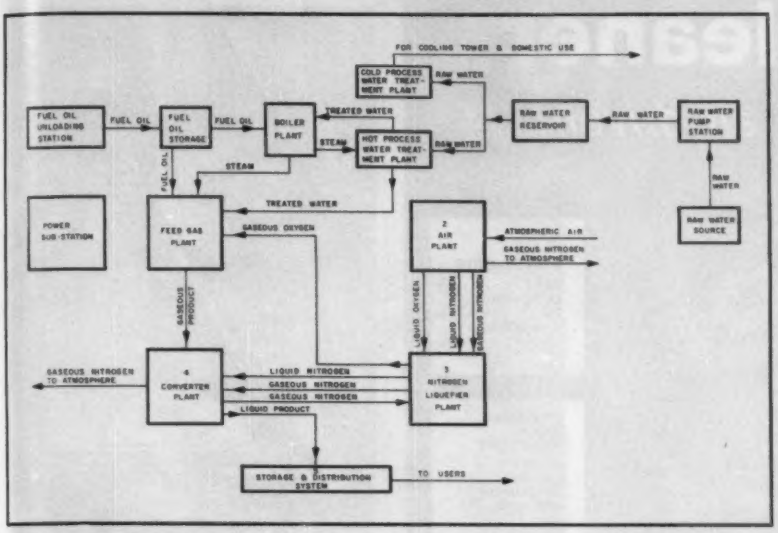
Heyden Newport Chemical Corp. plans to build a 24-million-pound-per-year maleic anhydride and fumaric acid plant at Fords, N. J. The $3.5-million plant is currently in the engineering stage, and will be completed late in 1960.

Consolidated Mining and Smelting Co. of Canada plans to build a 36,000-ton-per-year urea plant at Turner Side, near Calgary, Alb. The $5-million unit will be completed by Summer, 1960. It is Canada's second.

Texas Butadiene & Chemical Corp., New York, has completed, at its Channelview, Texas, plant, facilities for the recovery of propylene. The unit is the first to recover propylene in the ef-

For more data on advertised products, use Readers' Service Cards, last page.

fluent from the butane dehydrogenation process utilized by the company to produce butadiene and butylenes. The propylene, which is recovered in 80 percent minimum concentration, will be supplied to other petrochemical producers or used as feedstock to TB&C's own aviation alkylate operation.



New Liquid Hydrogen Plants for Allentown

Liquid hydrogen is being produced on a large scale at two facilities built and operated by Air Products, Inc., Allentown, Pa. Air Materiel Command (U.S. A.F.) awarded Air Products the contract for construction of the facilities.

One of these production facilities, Air Force Plant No. 74, is the world's only large tonnage unit of its kind (see flow diagram above). Plant No. 74 combines crude oil, air and water to generate hydrogen gas and utilizes electrical energy to refrigerate and liquefy the hydrogen.

The conversion of crude oil into liquid hydrogen is highly complex. About two-thirds of the atoms in a typical crude oil molecule are hydrogen atoms, or about one-sixth weight fraction. These oil molecules yield hydrogen directly and, in addition, hydrogen is recovered from water in the form of steam. This portion of the process also eliminates substantial amounts of carbon monoxide impurity, and is called a two-stage "steam shift" reaction. The CO and steam are converted catalytically into CO_2 and hydrogen. CO_2 is then removed by scrubbing with monoethanolamine. The gas is later purified to produce the purest hydrogen ever made, 99-999 percent. The highly purified hydrogen gas is then deeply refrigerated, subcooled below its liquefaction temperature and stored in specially insulated tankage.

American Oil Co.'s No. 2 Ultraforming unit has been completed at El Dorado. The Ultraformer, one of two at the refinery, is turning out a high-octane component to be blended with other stocks to make premium unleaded gasoline.

Natural Gas Storage Co. has completed a 15-20 percent expansion of a Girbotol purification unit at its Herscher, Ill., underground storage facility. The plant expansion was engineered and equipped by Girdler Construction Division of Chemetron Corp.

AviSun Corp. has begun installation of equipment to convert polypropylene to polypropylene film at New Castle, Del. The facility will produce 10 million pounds of film per year. A pilot plant for manufacturing polypropylene continuous filament and staple fibers also is being built at New Castle.

Arkansas Louisiana Chemical Corp. has placed new units on stream for the production of butane, propane, an ethane at its Magnolia, Ark., plant. The units are a part of a $3.2-million expansion.

Diamond Alkali Co. has finished a 20 percent expansion of caustic soda facilities at Deer Park, Texas. The increase ups daily capacity at Deer Park to 825 tons of caustic soda, 750 tons of chlorine, and 7.5 MMcf of high-purity hydrogen.

Olin Mathieson Chemical Corp. plans to begin glycerine production with a new unit to be built at Brandenburg, Ky. Other products to result from a $30-million expansion are epchlorohydrin, propylene oxide propylene glycol, and polypropylene glycols. Capacity will be doubled for ethylene dichloride. Olin

single

STEP

to profitable processing

If you're familiar with the one-step Houdry Dehydrogenation Process, you know the source of profit for a large share of this country's butadiene production capacity. Since the major expansion of the synthetic rubber industry began in 1955, more than 300,000 ton/yr of new capacity has been installed by Houdry licensees using this process for transforming butane to butadiene.

Don't get the idea though, that you have to make synthetic rubber to enjoy the advantages of the Houdry Dehydrogenation Process. It is also highly efficient for transforming butane to butenes, isobutane to isobutene, and other light hydrocarbons to mono- and di-olefins.

Simple . . . flexible . . . profitable. That's the Houdry Dehydrogenation Process. And it has these three very important characteristics because Houdry people designed it that way, and made it deliver.

They can do the same for you.

*

HOUDRY

PROCESSES

HOUDRY PROCESS CORPORATION

1528 Walnut Street, Philadelphia 2, Pa.

*Houdry means Progress . . . through Catalysis

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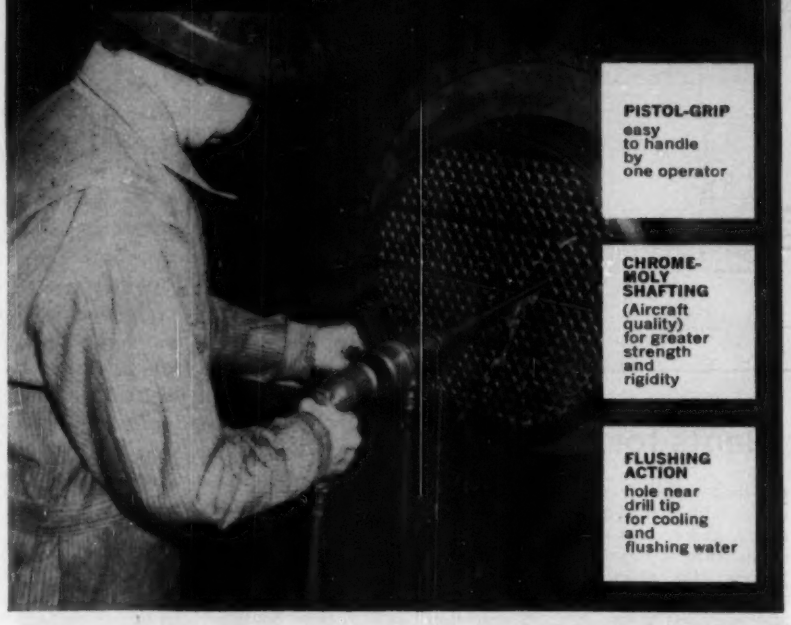
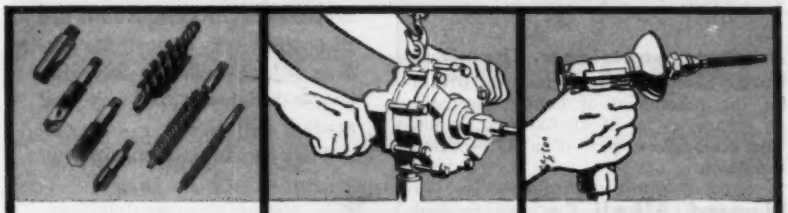
newest ELLIOTT tube cleaner

lightweight! air-driven!



for condenser and heat exchanger tubes

Lightweight. Powerful. Air-driven. Trigger-action control with speed governor to prevent shaft-whip. High-speed motor reduced through planetary gears to 1500 rpm. Integral water-feeding attachment with finger-action valve which controls flow of cooling water into hollow shaft and drill or brush. Built-in oil reservoir. Send for tube cleaner bulletin Y-48.



DRILLS AND BRUSHES FOR VARIED NEEDS
Brushes for light deposits. Four types of drills clean light, hard-heavy, hard-light, and gummy deposits.

SUSPENSION TYPE
Air, steam or electric heavy-duty motor, for removing hard, heavy deposits. Ball bearings absorb thrust in either direction.

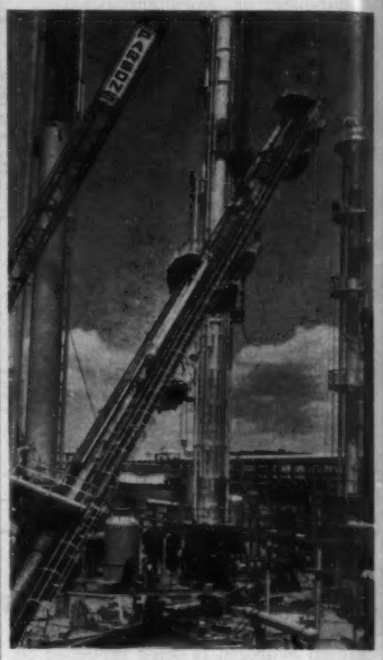
ELLIOTT JIFFY GUN
For extra-fast cleaning of light deposits in tubes ½ in. to 1¼ in. Air or water pressure shoots nylon brushes or rubber plugs through tubes.

ELLIOTT Company
Lagonda Plant—Springfield, Ohio

Y9-1

Building . . .

Mathieson will also install a sulfamic acid facility at Joliet, Ill.



Time-Saving Construction Technique for Vessels

A time-saving construction technique has speeded the erection of process columns at Shell Chemical Corp.'s glycerine unit, Norco, La., plant. The columns were completely outfitted before being hoisted upright onto their foundations.

The new glycerine unit, with an annual capacity of 35 million pounds, is scheduled to go on stream late this year. It will tie in with the new acrolein unit now being constructed at Norco.

Ordinarily, a vessel, completely bare of any accessories, is hoisted into position on its foundation. The platforms, ladders and major piping are installed next. Then an iron scaffolding is erected around the tower from which workmen install the insulation, minor piping and electrical fixtures. Painting completes the job. This intricate iron network must then be removed before the unit is ready for operation.

With the current system, however, the bare vessel is completely fitted with the necessary hardware on the ground. Except for areas where the hoist's hook will be attached, the vessel is completely insulated. The piping, ladders and platforms are attached, and electricians follow with wiring and lighting fixtures. Then, painters spray the exterior, moving easily from one end of the tower to the other.

The new procedure also provides easy access to materials and allows several different stages of construction to proceed simultaneously on more than one vessel.

Offsite construction for the process

For more data on advertised products, use Readers' Service Cards, last page.

It's who's up front that counts

To the design engineer, "follow-the-leader" sometimes seems to be an industrial pastime.

Imitations always appear on the market to follow a leader – and, when they do, it is best to *choose the leader*, because:

If it is good enough to imitate, it must be superior!

When you specify fractionating trays for your next important installation, keep in mind that, "It's *who's up front* that counts"!

Then, count on Koch FLEXITRAYS for superior performance!

For extreme flexibility, higher capacities, and l-o-n-g-e-r cleaning cycles, specify the superior tray that others chose to copy – the Koch FLEXITRAY . . . *now in use by major companies in more than 1,000 non-captive installations!*

Write, wire, or phone your nearest Koch representative or

KOCH

ENGINEERING COMPANY, INC.
321 W. Douglas Ave., Wichita 2, Kansas

"Continuing progress through research"

REPRESENTATIVES

BUTTE, MONTANA — G. M. Wallace & Co., P. O. Box 208
DENVER, COLORADO — G. M. Wallace & Co., 324 Denham Bldg.
EL PASO, TEXAS — G. M. Wallace & Co., Suite 511, Electric Bldg.
HOUSTON, TEXAS — Alpha Engineering Co., P. O. Box 12371
KANSAS CITY 13, MISSOURI — Sample Brothers, P. O. Box 7061
NEW YORK 17, N. Y. — F. J. McConnell Co., 60 East Forty-second St.
OAKLAND, CALIFORNIA — Engineered Process Equip. Co., 600 Sixteenth St.
PARK RIDGE, ILLINOIS — M. B. Fisher, 1521 Courtland Ave.
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PITTSBURGH 19, PENNSYLVANIA — D. D. Foster Company, 2210 Koppers Bldg.
SALT LAKE CITY, UTAH — G. M. Wallace & Co., Continental Bank Bldg.
SOUTH CHARLESTON, WEST VIRGINIA — D. D. Foster Co., 411 "D" St.
ST. LOUIS 17, MISSOURI — Sample Brothers, 2010 Big Bend Blvd.
TULSA 16, OKLAHOMA — Myers Aubrey Co., P. O. Box 5436

FOR ⅛ TO 1½ INCH BRANCH CONNECTIONS

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NEW W-S TeeLet SLASHES TEE COSTS 50% OR MORE!

The new W-S TeeLet replaces conventional Tees of cast or malleable iron, welded or forged steel . . . requires fewer stock sizes. Available in sizes from ⅛ to 1½" IPS, TeeLets are fully machined from forging quality solid steel bars and adapt to run-pipe sizes to 36". They require no additional joint strength calculations for any ASTM A-53 or A-106 Grade B run-pipe of Schedule 40 or 80.

What about cost? A size-by-size comparison with conventional Tees shows TeeLets average less than 50 per cent of the cost you now pay. A W-S TeeLet, with screwed, socket-weld or butt-weld ends, requires no shaping, fitting, beveling or extra alignment. You can connect to the run-pipe at any point. Short heights mean easy inspection of the attachment weld or back-weld, if desired.

A W-S TeeLet costs less to buy, less to install than anything you can buy or make. For complete information, prices, and names of distributors, write: *Forge and Fittings Division, H. K. Porter Company, Inc., Box 95, Roselle, N. J.*

FORGE AND PORTER FITTINGS DIVISION

H.K.PORTER COMPANY, INC.

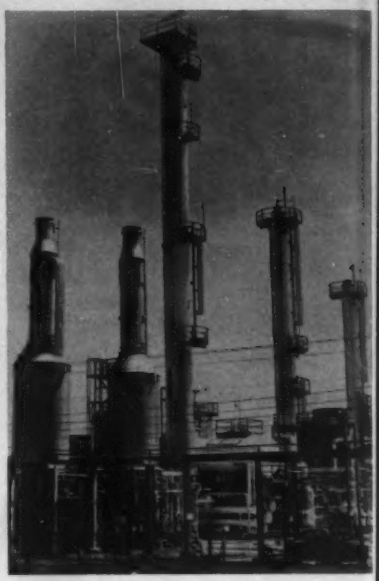
PORTER SERVES INDUSTRY: with Rubber and Friction Products—THERMOID DIVISION; Electrical Equipment—DELTA-STAR ELECTRIC DIVISION, NATIONAL ELECTRIC DIVISION; Specialty Alloys—RIVERSIDE-ALLOY METAL DIVISION; Refractories—REFRACTORIES DIVISION; Electric Furnace Steel—CONNORS STEEL DIVISION, VULCAN-KIDD STEEL DIVISION; Fabricated Products—DISSTON DIVISION, FORGE AND FITTINGS DIVISION, LESCHEN WIRE ROPE DIVISION, MOULDINGS DIVISION, H. K. PORTER COMPANY de MEXICO, S. A.; and in Canada, Refractories, "Disston" Tools, "Federal" Wires and Cables, "Nepcoduct" Systems—H. K. PORTER COMPANY (CANADA) LTD.

Building . . .

units and additions to the plant's administration building, change house, shops and warehouse are on schedule. The latter are being occupied as completed.

Distillation Unit Complete At Derby's Wichita Plant

Derby Refining Co. has started up a 1,700 bpsd alkylation unit at Wichita, Kan. Designed to yield a 100+ octane leaded alkylate for use as a blending component in the production of high



octane motor fuel, the unit takes its C_3-C_4 olefinic feed stock from the gas recovery section of Derby's catalytic cracker. Isobutane makes up the balance of the unit's feed stock. Flexibility of design allows it to process either a C_3-C_4 charge or C_4 alone.

Designed and licensed by Universal Oil Products Co., the new alkylation unit was built by Procon, Inc. It is in a refinery expansion program.

Pacific Carbide and Alloys Co., Portland, is planning to build a 5-10-million-pound-per-year vinyl acetate monomer plant.

Sunray Mid-Continent Oil Co. has completed a new natural gasoline plant at Carancahua Bay in Jackson County, Texas. The 30-MMcf-per-day plant produces 27,000 gallons per day of propane, iso-butane, and natural gasoline.

Cosden Petroleum Corp.'s Big Spring, Texas, refinery is planning an expansion to double facilities for polybutene production.

Imperial Chemical Industries, Inc.'s subsidiary, Industrias Quimicas Argentinas Duperial, S.A.I.C., Buenos

Read up to 288 temperatures at this Honeywell "Operator's Desk"

This compact console type Operator's Desk makes it possible, from one central location, to read as many as 288 thermocouple points, or 192 points with identifying card holders. Its *ElectroniK* Precision Indicator and switch assemblies are mounted for ease of reading whether the operator is sitting or standing.

The *ElectroniK* Precision Indicator, accurate to 1/5 of 1% of full scale, can be of single range, double range or extended range type. Use it with all types of thermocouples, millivolt actuation, or a combination of the two. The desk can be supplied with a telephone dial system for thermocouple selection, rather than key or pushbutton switches. Additional equipment such as lights and clocks can be built in.

Servicing is simplified. Instrument and switch terminal blocks are in the lower rear portion of the desk, readily accessible from the back of the console. All wiring enters from the bottom of this compartment.

Get complete details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

H HONEYWELL *First in Control*

For more data on advertised products, use Readers' Service Cards, last page.

plan now for future piping extensions!

Welding extension to 8" line without shutdown of line. Pressure stopped-off at dead end.

install **MUELLER**® *Extension Stopper Fittings*

H-17251 Extension Stopper Fitting for Dead End Extensions
Pressures to 230 p.s.i.
Sizes: 3", 4", 6" and 8"

■ **Plan ahead for future system expansion by capping all dead ends with Mueller Extension Stopper Fittings at the time the piping is installed.**

Then, when the line must be extended, just follow these four simple steps:

1. **Stop-off line at fitting with Mueller Line Stopper Equipment. (No drilling needed!)**
2. **Cut off capped end of fitting.**
3. **Weld your new piping to fitting.**
4. **Remove stopper and "button up" fitting.**

All of these steps are performed quickly and in complete safety. There is no interruption of processes on the existing line and no need to install expensive control valves.

Remember these fittings for your next piping installation. They will save you time and money when future extensions must be made.

Write for complete information on these and other sizes and styles of Mueller Extension Stopper Fittings.

NO-BLO®

These fittings are typical of the attention to detail in research, design and engineering that becomes a part of every Mueller No-Blo product manufactured for the petroleum industry.

MUELLER CO.
DECATUR, ILL.

Factories at: Decatur, Chattanooga, Los Angeles; in Canada: Mueller, Limited, Sarnia, Ontario

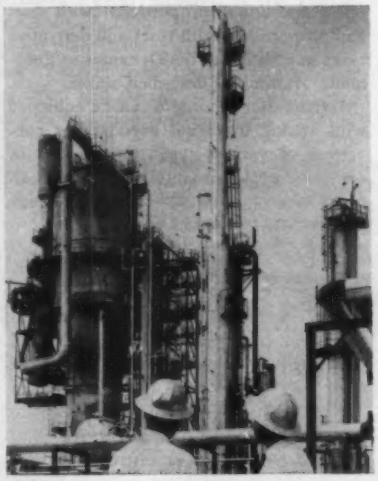
Building . . .

Aires, has received $4.2 million from the parent firm toward a $6.58 million expansion program. Units to be installed include carbon bisulfide, sulfuric acid, phthalic anhydride and hydrogen peroxide.

The Dow Chemical Co. has completed a new industrial incineration plant at Midland, Mich. The six-acre, $2.3-million plant was built to reduce air pollution by Dow's chemical complex, which produces 1,100 products in 600 buildings on a 4,500-acre site. The plant can dispose of a quarter-million pounds daily of refuse and tars.

Cat Cracker Expansion for B-A at Clarkson, Ontario

A $1.5-million expansion of the catalytic cracking unit at British American Oil Co.'s Clarkson, Ont., refinery has boosted unit capacity 50 percent—from



12,000 to 18,000 bpd. The expansion, which took four months, does not increase crude running capacity of the 61,500-bpd refinery.

Montecatini Co. is designing and constructing a fertilizer and chemical plant for Fertilizante Sinteticos S. A., Callao, Peru. The $10-million unit will produce ammonium nitrate, ammonia, nitric acid, nitric fertilizers and ammonium sulfate. Already complete are air fractionation towers for nitrogen separation.

The Dow Chemical Co. plans to build a polyethylene film plant near Fresno, Calif., with completion expected early in 1960. Facilities will occupy four acres of a 24-acre site southeast of the city.

Shell Chemical Co. is planning a commercial-scale polyisoprene plant at Torrence, Calif. The unit will produce 20,000 tons per year.

Fisons, Ltd. and Shell Chemical Co. have completed the second stage of a joint project for construction of two fertilizer plants in the Thames Estuary (Stanford-le-Hope), England.

Sun Oil Co. has completed a $4-million natural gasoline plant in the La Verne field, Harper County, Okla. The 100-MMcf-per-day plant, in which Sun has a 30 percent interest and 29 other companies have a 70 percent interest, produces 117,000 gallons of liquids daily.

Kimbell-Campbell Refining Co. has completed building a 2,500-bpd catalytic reformer at Bloomfield, N. M. Under construction since February, the plant will process raw distillate into 90-100 octane gasoline.

Hooker Chemical Corp. has begun expansion of its North Tonawanda, N. Y., formaldehyde plant. To up the company's output by 10 percent, the plant will be completed within six months.

General Electric Co. is planning to build a polycarbonate resin plant near Mt. Vernon, Ind. To go into operation by late 1960, the plant will produce 10 million pounds per year.

Continental Carbon Co. is planning a $2-million expansion of its Lake Charles, La., carbon black plant. The program will up the facility's capacity from 45 million pounds annually of high-abrasive carbon black to 70 million pounds. Work is to begin immediately.

Union Carbide Corp. plans to up its Texas City polyethylene capacity by 25 million pounds. The plant currently has a 65-million-pound-per-year capacity.

Continental Carbon Co. plans to build a carbon black plant in Rotterdam, the Netherlands. The 15,000-ton-per-year plant will cost about $2.5 million. Construction of the unit is to start soon and be completed in early 1960.

Standard Oil Co. (New Jersey) plans to construct a refinery at Karlsruhe, West Germany. Scheduled to be completed late in 1962 and placed in production by January, 1963, the plant will be built by Esso, A.G.

Allied Chemical Corp.'s National Analine Division is planning to increase maleic anhydride production at Buffalo, N. Y., and Moundsville, W. Va. Expansion at both locations is to be completed late this year.

Supertest Petroleum Corp. is tentatively planning a $50-million refinery in the London, Ont., area. The marketing firm reports it is waiting until the end of the current "gasoline surplus" before making definite plans.

Union Carbide Corp. plans to build a plant for ethylene oxide and derivities at Prioli, Italy. The unit will be operated by Celene S.P.A. jointly owned by Carbide and Societa Edison, Milan. The 26.5-million-pound-per-year plant will begin production by mid-1960.

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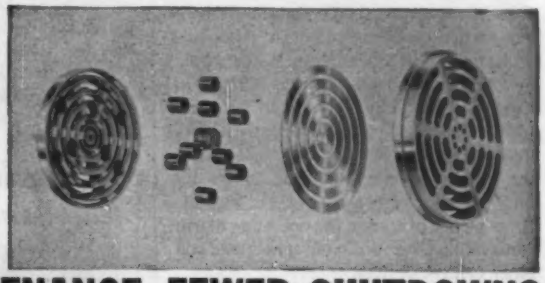

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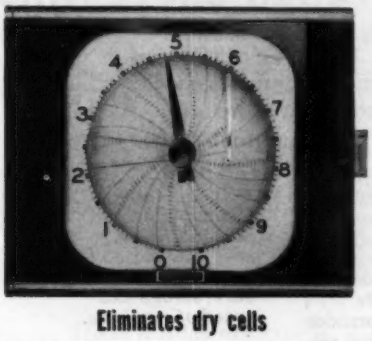
"Over design" insures reliability

The Dynamaster's simple design with few moving parts, plus "over design" in all components insures long life. Easy to use and service, the instrument requires little or no maintenance. Rugged construction . . . ideal for industrial plants, and pilot plants . . . gives the Dynamaster exceptional vibration resistant qualities.

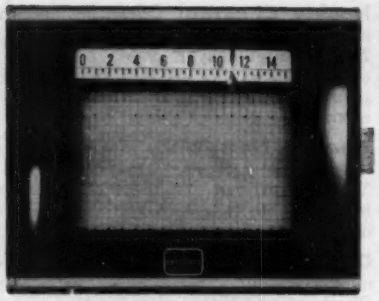
High instrument accuracy

Conservatively rated components, Bristol's careful design and manufacture, combined with the proved Dynamaster motor-driven null-balance principle insure high instrument accuracy and precision in fast electronic measurement and control. Used in miniature as well as full-sized Dynamasters, the motor-driven null-balance design not only provides high accuracy, but also affords plenty of torque for operating alarm contacts, analog to digital converters and other control devices.



Eliminates dry cells

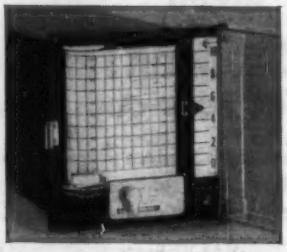
"No-Batt" continuous standardization, available as an optional feature, accurately and automatically standardizes the potentiometer against standard cell continuously, without interruption to service. Dry cells and the usual standardizing mechanism are eliminated. **T.M. Reg. U.S. Pat. Off.*



Wide range of models

Dynamaster round chart instruments are available in one- or two-pen models. Strip chart models are available as single-pen, two-pen or multiple-record instruments up to 24 points. Dynamaster models for research and testing include: High speed (0.4 sec) Recorders; Two-Pen Recorders; X-Y Recorders (function plotters); Extended Range Recorders; Adjustable Span and Zero Recorders.

Electronic Dynamaster Pneumatic Transmitter



The Dynamaster is now available as a recording or indicating pneumatic transmitter. This new miniature instrument is offered as a potentiometer, pyrometer, d-c bridge, or a-c bridge for making such measurements as resistance, conductivity, strain, and many others, or it can be a differential-transformer receiver. It continuously transmits a 3-15 psig air pressure signal which can be used to operate recording and controlling pneumatic instruments, such as Bristol Metagraphic Instruments. Full size Dynamaster air control instruments are, of course, also available.

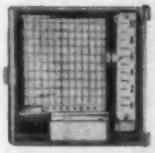
Many electric and pneumatic controllers

Dynamaster round- and strip-chart instruments are available with a wide variety of controllers, both electric and pneumatic.

Electric controllers include on-off, proportional input, 3-position, proportioning, proportional with automatic reset and time program models.

Pneumatic control models include on-off, proportional, proportional with reset and proportional with reset and derivative types in addition to the Dynamaster Pneumatic Transmitter described above.

Dynamaster recorders can be equipped with analog to digital encoders or converters of various types for readout or computer use. This feature extends the already wide range of applications for which Dynamaster instruments are suited.



"Plug-in" miniatures

Bristol miniature Dynamasters (Series 663) take only 5" x 5⅛" panel space. A true plug-in chassis permits 10-second changeover from an indicator to recorder, lets you plug in spare instruments with minimum interruption to control. Miniatures utilize the same highly accurate, motor-driven null-balance principle as full sized Dynamasters which assures ample torque for operating auxiliary equipment or contacts—another advantage over ordinary galvanometer type instruments.

Dynamaster records stomach acidity

Here's a novel Dynamaster application in medical research. Dr. Joseph Gambescia, at Hahnemann Medical College and Hospital, uses a Bristol Recording Potentiometer to study effects of various alkalinizing agents on stomach acidity. The transducer that feeds the Dynamaster is a specially developed glass electrode which is swallowed by the subject.

NEWS AND NOTES

recording and telemetering instruments from Bristol

The now-famous Shippingport, Pa., Atomic Power Station is the United States' first full-scale central station nuclear power plant devoted exclusively to civilian use. Westinghouse Electric Corporation designed and developed the nuclear portion of Shippingport under the direction of and in technical cooperation with the Naval Reactors Branch, U. S. Atomic Enerngy Commission.

The Bristol Company is one of the intrument suppliers furnishing electronic potentiometer and bridge instruments used here.

Complete temperature profiles increase yield at LCA

Control of time-temperature relationships in decrepitation of lithium ore is critical. Too high temperatures in the huge 250' rotating kiln at the Lithium Corporation of America, Bessemer City, N. C., plant could cause clinker rings and reduce yield. If temperatures are too low the desired chemical conversion will not take place. The problem was how to continually measure internal temperatures throughout the entire length of the kiln. Bristol instrumentation was the answer.

Instruments provide complete temperature profiles within the initial kiln and monitor every step of the process to the final continuous crystallizer. Operators above spot checks temperatures at Bristol panel board. B-47

Testing the Titan

A panel of Bristol electronic instruments at Martin-Denver Division's Propulsion Laboratory above aids propulsion tests of the Titan ICBM, largest of the Air Force missiles. These Dynamaster recorders were installed as part of the test equipment supplied by Pomona Division, Marquardt Aircraft Co., formerly Associated Missile Products Co. They are used to check out kill parameters during tests. Monitoring engineers can stop tests if the red line limits on critical readings are exceeded.

Record wind tunnel data

Fourteen strip chart Dynamaster millivoltmeters record aerodynamic data from variable resistance strain gages on models under test in the Boeing supersonic wind tunnel. Each recorder is equipped with analog-to-digital converters which convert the Dynamaster potentiometer shaft rotation to digital output. The complete hookup makes possible immediate presentation of computed data simultaneously with the running of the test.

New Dynamaster fits standard 19" relay rack

Many Dynamaster models now fit into standard 19" relay racks without modification to rack or instrument. These are the first such instruments that may be so installed without cutting or masking. For more facts, write: The Bristol Company, 111 Bristol Road, Waterbury 20, Conn.

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The Two Processes of 'Memory'

Recall and recognition are the two ways for remembering previously learned material. You'll learn all about these two plus some valuable information about why you sometimes forget

HOW TO REMEMBER PART 2

John D. Quinton
Tennessee Gas Transmission Company, Houston

IN THE FIRST PART of this article we discussed the learning process which emphasized "acquiring" knowledge. We considered such items as the intent to learn, paying attention, learning names and faces, looking for meaning, proper mental set, and many others.

Now, in turning to remembering and forgetting, we will give special attention to the processes of retaining what we have learned and the why's and wherefore's of forgetting.

REMEMBERING

Memory or remembering is the retaining of all or part of what we have acquired. Once again it should be emphasized that efficient learning will bring about good retention; i.e., memory.

There are two processes of remembering. Let's consider each separately and see the likenesses and differences of each.

1. Recall. This term is generally used when you are trying to remember some specific thing that you have learned. One of the main causes for failure to recall is the interference of other recalled material. For example you are asked, "Do you recall the name of the fellow that fixed the car?" The many names that flood your mind are cases of recall, too. This interference can cause the name you are seeking to escape you. To remedy this, do not try to recall the name for a time and give your mind a "rest." As the other names gradually drop out by your rejecting them, the correct one will appear.

You will notice that in recall, you use no visual cues or multiple choice answers. If such aids are used, then the remembering process is not recall but recognition.

To test your own or another's immediate recall, or memory span, try the following test. Below are a series of digits ranging from 4 to 12. Read each series of digits to a friend and let him repeat them. Continue giving him an additional digit each time until you have reached his limit. This is all he can recall and is known as his memory span.

2571
36497
584135
3969152
50719647
369260851
3041698934
74650143962
797239517152

2. Recognition. Recognizing material from our past experiences is much easier than recalling. That is one reason students prefer multiple-choice and matching questions rather than completion and essay. The answer is before them and they don't have to recall it.

To test yourself on your recognition ability, examine the following symbols for one minute. Then look on the next page and check the ones that you saw in the group below.

You will note that you had some

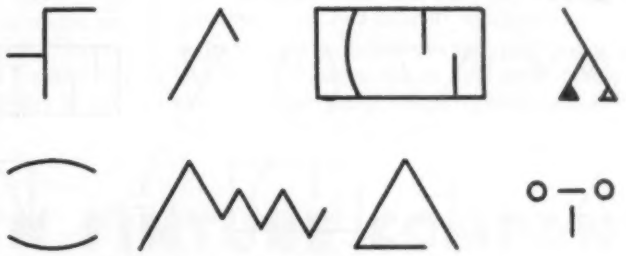

FIGURE 3—Test your ability to recognize.

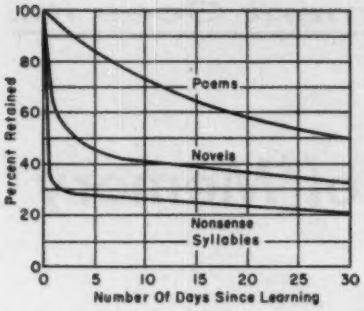

FIGURE 4—Forgetting follows a definite pattern.

false-recognition. Some of this is due to figure similarity but much of it is due to your own wishes, desires, goals, etc. In short, our personalities determine, to a degree, how good our memory is.

FORGETTING

It is hardly necessary to demonstrate the process of forgetting for, unfortunately, it is no stranger to any of us. But it might help us to remember better if we know the how and why of forgetting.

1. Rate of Forgetting. Regardless of the causes for forgetting, it tends to follow a definite course. Look at Figure 4 which shows some typical forgetting curves.

You will note immediately the rapidity with which we forget. This rapid deterioration is true for all of us. In fact, many people are rather startled when they realize that within one or two days over 50 percent of what they learned is gone.

This suggests very strongly that we should repeat our practice and drill (overlearning) immediately after the original learning. (Overlearning was discussed in detail in Part 1 which appeared last month.) This means at least by the next day if we wish to retain the material permanently.

It is also quite apparent from this graph that forgetting occurs at different rates due to the type of material learned. The more meaning the material has, the less the rate of forgetting. This substantiates the "look for meaning" rule of learning (also discussed in Part 1).

2. Why Do We Forget? Taking a cue from the forgetting curve, the first answer would seem to be that we forget because the neural traces grow dimmer with the passing of time. Studies show, however, that there is more to forgetting than just the lapse of time. More important, it seems, is what takes place during the time between learning and remembering. Many experiments have shown that if there is no mental activity between the learning and the reproducing of the material, forgetting will be less than if there is some form of mental activity.

For example, if a group of children studied a poem for 30 minutes, then one half rested their heads on their desks and the other half studied arithmetic for 30 minutes, the inactive group would remember more of the poem. This is known as "retroactive inhibition."

This suggests that we should keep relatively inactive between the time we learn a speech, formula, facts for a conference, etc., and the time we want to remember the learned material.

This inactivity will pay even more dividends if it is spent in sleep. For studies show that you will remember more of what you have learned if you go to sleep immediately after the learning period. This suggests that if you are preparing for an important project on the morrow that, instead of learning your material early in the evening and then have some social activity, it would be better to learn the material after the activity and go straight to bed.

We can say, then, that the interference of new material is as significant if not more significant than the mere lapse of time in causing rapid forgetting.

3. Emotion and Forgetting. If a person has never experienced the feeling of frustration and embarrassment because he couldn't recall a name which he "knows as well as my own," then he is fortunate indeed. This seems to be a malady that befalls nearly all of us. The well rehearsed speech is suddenly forgotten when the toastmaster says, "And here is our speaker for the evening, Mr. Brown." And the embarrassment when we start to introduce our best friend to an important person and we can't remember the friend's name.

What causes this sudden forgetting? The emotions are causing a great deal of the difficulty. As some wag has said, "When the emotions come in the door our memories and intelligence go out the window."

Fear, anxiety, excitement, love, hate, all interfere with our memories. This is illustrated by the incident where the groom forgot the bride's name after the wedding ceremony.

To counteract this common pitfall, you should try to keep a "cool" head. Slow down, take a deep breath, and take the pause that refreshes the memory.

In closing, it might be wise to reemphasize the fact that the use of any memory "system" to help facilitate remembering does not develop an entity called "memory." If the system does help the person to remember, then it is teaching him better and more efficient learning techniques. In addition, if the person does not continue to use the principles and methods of efficient learning his "memory" will return to its former state of inefficiency.

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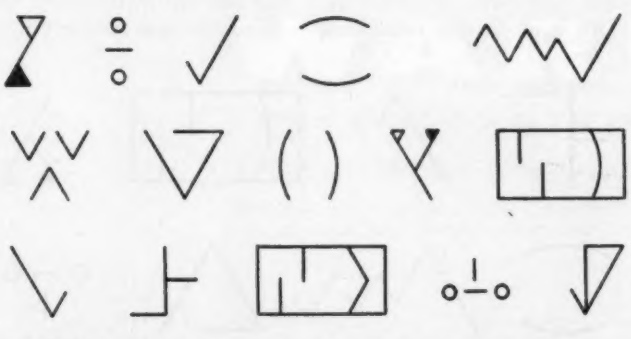
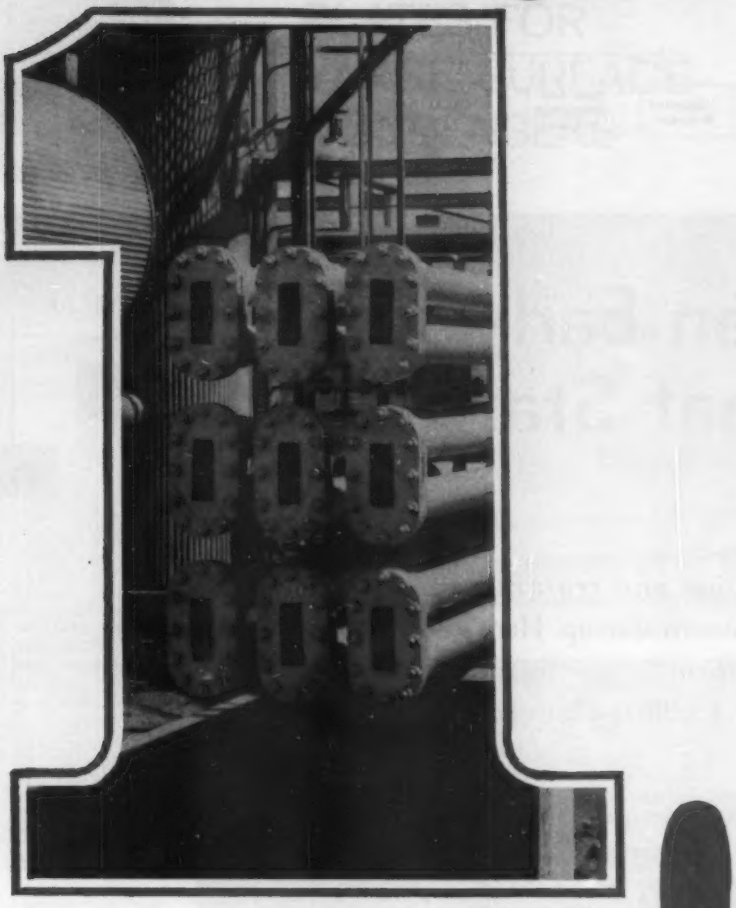


FIGURE 5—Check the same symbols which appeared in Figure 1.

The Optimum Standardization on Heat Exchangers is...



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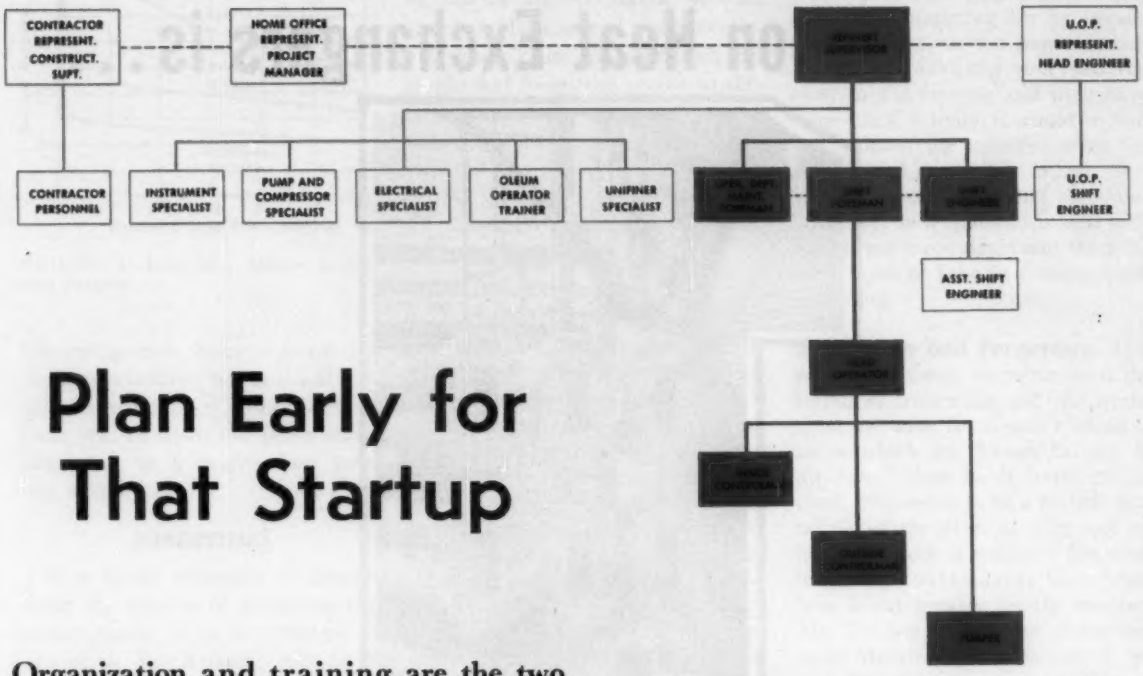


Plan Early for That Startup

Organization and training are the two keys to smooth startup. Here's how Union Oil used them to save time and money in putting a Unifiner-Platformer onstream

FIGURE 1—The unique features of this organization used for the startup of Union Oil's Unifiner-Platformer make it different from any organization used previously. The solid color blocks represent the refinery operating department that was responsible for the continued operation.

E. P. Barnett
Union Oil Company of California
Wilmington, Calif.

IN 1957 Union Oil Company of California successfully started up a new Unifining-Platforming unit at its Los Angeles refinery. This startup was somewhat unique in the definition of responsibilities among process licenser, design and construction contractor, home office group, and the refinery. A refinery-centered organization was used instead of one that was contractor or home office centered in order that the valuable knowledge and experience gained during the initial operations would be retained within the normal refinery operating group. Shift foremen were given key assignments and a small core of specialists executed important functions throughout the design, construction, and startup stages.

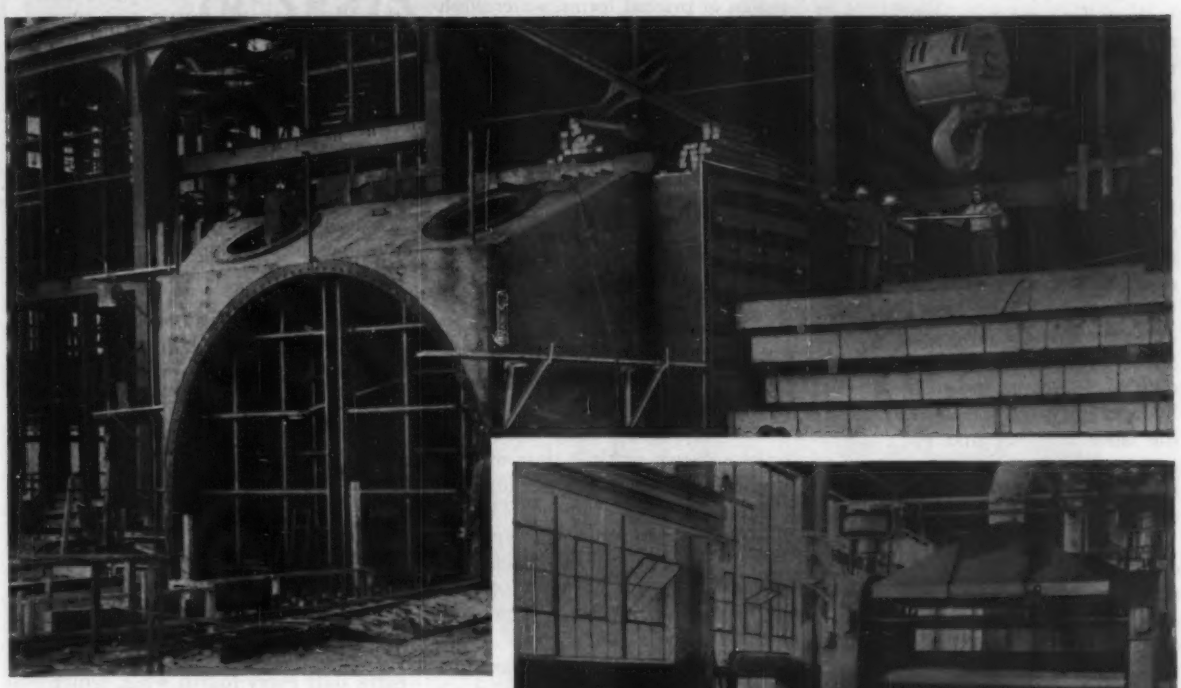
In Union Oil, a major new construction project is usually handled by the home office engineering and construction group and the refinery works with this group during the design and construction stages. However, the home office group is responsible for seeing that the units are properly designed, constructed and turned over to the refinery in a "ready-to-operate" condition. The startup preparations discussed in this article are those necessary on the part of the refinery and, for the most part, are divorced from the problems associated with the design and construction of the units.

The Los Angeles Platformer has a rated capacity of 12,900 bpsd of reactor charge and the Unifiner has a rated capacity of 14,500 bpsd of reactor charge. C. F. Braun and Co., Alhambra, Calif., designed and constructed the unit.

Early Stages. During the early design stages, a part-time refinery committee worked with the contractor and the home office group. This committee presented the refinery's thinking concerning the design and selection of equipment, thus, the refinery's experience was incorporated at a time when changes were less costly. During this stage and during construction, we resolved many problems and reached common understandings regarding final construction decisions.

About two or three months prior to starting construction, the refinery supervisor was selected to be re-

7-TON COPPER-ALLOY PLATES FOR LARGE SURFACE CONDENSERS



TOP: View of the new Clinch River Plant of Appalachian Power Co., at Carbo, Va. **ABOVE:** Tubing one of the two huge Allis-Chalmers surface condensers. The 26' x 15' openings in the shell use two Anaconda Leaded Muntz Metal-274 plates, each 156" x 189" x 1½" and weighing 13,700 lb. American Brass furnished the eight plates required, as well as the Arsenical Admiralty-439 tubes for the unit above — 19,100 lengths, ⅞" x .049" x 30'. **RIGHT:** The big rolling mill at American Brass Company's Detroit Division which produced the plates.

THE unusually large plates required for the tube sheets at Clinch River Plant are standard items of The American Brass Company, which produces plates of copper and a number of copper alloys in rectangular sizes up to 156 inches in width and 15,000 pounds in weight. The maximum standard limits for circles are 160 inches in diameter and 11,000 pounds in weight. Half circles can be produced up to 13,000 pounds in weight.

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SPECIAL JOBS. Whenever you have a problem involving extremely large plates in standard or special copper alloys, The American Brass Company will gladly assist in its solution. For general information on Anaconda Condenser Tubes and Plates write for Anaconda Publication B-2: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

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sponsible for the preparations, the startup, and the operation of the units. This man coordinated the refinery's interests during construction and worked closely with the home office project manager who was actually responsible for the construction.

About six or seven months prior to startup, we formulated plant staffing plans and discussed contractual details with representatives of the labor union. The various labor-management problems associated with staffing the new unit required two to three months to resolve, and these meetings were started none too soon.

Personnel Selection. We completed actual selection of the operators to staff the units about three months prior to startup. This is an extremely important function. In fact, it would be difficult to designate any other item more important to the efficient operation of a new unit than intelligent, experienced, and well-trained operators. These men were selected within the seniority and qualification provisions of the labor contract and each applicant was interviewed by one or more supervisors familiar with his previous experience and ability.

The startup and initial operation of a new plant usually requires extra staffing. As a consequence, we overstaffed the unit by about one-third during this period. This also provided trained personnel available for relief for vacations, sick leave, attrition, etc.

Preparing the Manual. One of the most time-consuming jobs was preparing the operating manual. We started on this project about four or five months ahead of startup, with most of the work being done by the startup engineers who were gradually being made available. The engineers' talents for putting thoughts into words and drawings were effectively utilized. In turn, they became familiar, at least on paper, with the equipment in the unit and how it was supposed to function.

The operating manual presented a detailed coverage of all phases of the operation and the equipment using numerous small drawings and sketches. It included such items as fire and safety precautions, design summaries, chemical reaction discussions, process descriptions, utility and auxiliary systems, startup and shutdown procedures, etc.

We felt that time spent by an engineer at this stage paid large dividends later in training operators. Altogether, preparation of the operating manual required about six man-months of work, excluding stenographic and drafting time.

More Tasks. There were numerous other instructions we had to complete prior to the time when operator training began. These were: the design of printed forms, water washing and drying instructions for the initial startup, condensed operating controls, training agenda, work guides, qualification examinations, equipment stencil lists, and the ordering of special equipment for sampling and control testing at the unit. Most of this work, requiring about three man-months, was done by the startup foremen who were made available on a part-time basis during this period.

Equipment Inspection. As the construction progressed and the various pieces of equipment began to arrive on the job, an operating department representative made a thorough inspection of each item of equipment as soon as it was installed. This included reactor, tower and vessel internals; pump, turbine and compressor installation; instrumentation, electrical facilities; and process and utility piping.

This phase of inspection was independent of the construction engineers' observations and was primarily made to check the condition of the equipment and to obtain conformance with refinery standards. In general, the contractor did an excellent job with the details and with the overall construction. However, as is the case in any project of this magnitude, the refinery inspections revealed a few errors and deficiencies that were usually easy and inexpensive to correct at that stage.

Personnel Training. Startup engineers and foremen were selected about six months prior to startup so they could participate in a gradual familiarization training program. Although they were busy on their normal assignments at the time, they attended a weekly classroom training session of two to three hours conducted by the supervisor in charge of the startup, although some of the training material was prepared and presented by some of the startup engineers.

During this period each foreman and engineer visited our Oleum refinery to observe a Unifiner-Platformer in operation. Most of them had the opportunity of witnessing a shutdown or a startup as they discussed the detailed operations of the units with the operators. This on-the-job training proved to be very valuable, especially since Oleum personnel freely discussed the lessons they had learned during two years of operation.

Four weeks prior to the continuous staffing of the units, we conducted a one-week training program for startup foremen and engineers. This provided a final review of the operations and equipment so they would be better qualified to train the operators beginning the following week.

Forming Crews. Full-time training of the operators took place during the three-week period preceding the staffing of the units. At the beginning of the training period we divided the group into four crews. Each crew consisted of six operators, two engineers, and one shift foreman who was in charge of the crew. These crews were kept together from the first day of training through the first two months of operation.

When around-the-clock coverage began, each crew had to work an extra shift every fourth week, which was equivalent to an average work week of 42 hours. This is called "four gang" scheduling. While the use of intact crews is desirable for the teamwork that is required in normal operations of units, it is an essential part of good startup.

On the first day of training, each person received a copy of the operating manual. The entire group spent each morning in the classroom learning the material in the operating manual. The afternoons were usually spent at the nearly-completed unit, with each crew reviewing in the field the equipment they had studied that morning. We gave written and oral examinations and each foreman was responsible for making sure every operator in his crew was well qualified.

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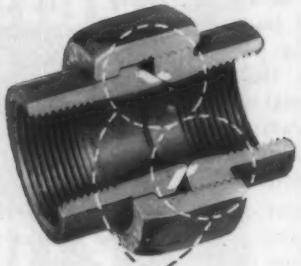

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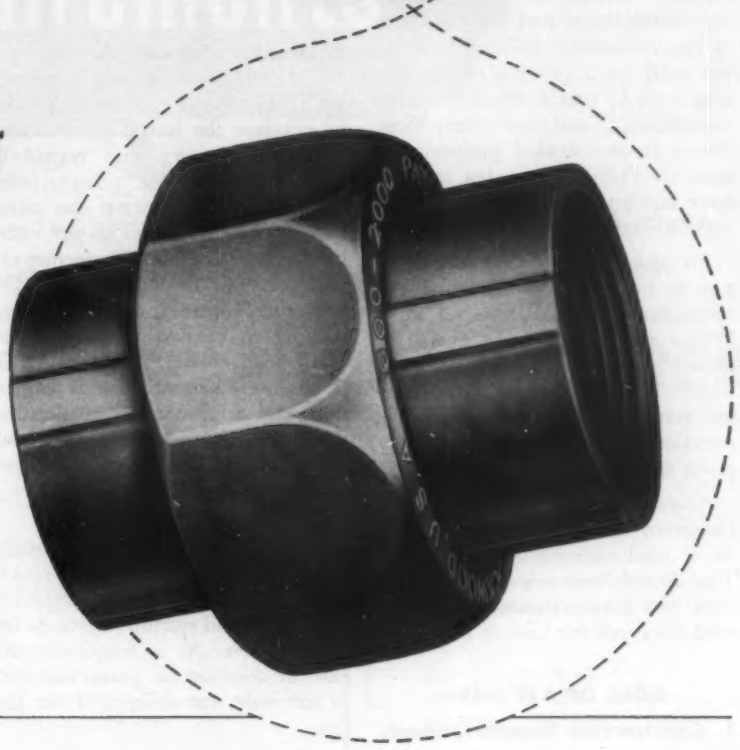

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quires the combined efforts of many people of various talents, and it takes a good organization to minimize the confusion. Figure 1 shows the organization used for our Unifiner-Platformer. Its unique features make it different from any startup organization used previously at Union Oil. The shaded positions represent the normal organization of the refinery operating department that was to be responsible for the continued operation of these units.

In fact, this exact organization is still in effect today. This group formed the nucleus of the startup organization and had the assistance of the various specialists shown. As the need for a given specialist disappeared, he was dropped from the organization, until finally only those shown in the shaded positions remained. This eliminated a troublesome interim period which had been encountered in other startups.

Previously, staff engineers were put in line positions directing the operations and the crews on shift. When the units were running smoothly, the engineers, with their wealth of knowledge acquired during startup, would return to their normal jobs leaving a comparatively green supervisory force in charge.

As shown on the chart, there were numerous assignments filled and each had definite responsibilities. The dotted lines primarily indicate lines of communication and the solid lines indicate lines of authority.

ROLE OF KEY MEN

1. Construction Superintendent. This man was, of course, thoroughly familiar with the unit and with the subcontractors who furnished much of the equipment. Reporting to him was a small core of craftsmen and their supervisors who remained on the job during the early stages of the operation. The debugging of equipment always presents problems and this case was no exception. The construction superintendent's contributions during this phase of the startup proved to be very helpful.

2. Project Manager. As the representative of the home office engineering and construction group, the project manager had worked on this project since its conception. He was a chemical engineer and was the person most familiar with details of process design, equipment sizing and selection, material selection, piping and instrumentation—in fact, the entire unit.

He was largely responsible for the cooperative relationships that existed among refinery, home office, and contractors' personnel. He also established and maintained a strict inspection of all equipment as it was installed. He worked closely with contractors' and refinery personnel during the entire startup, and his assistance and guidance proved invaluable.

3. Licenser Personnel. Universal Oil Products sent four engineers to assist with the startup and to evaluate the initial performance of the Platformer with regard to process and catalyst guarantees. These men were startup specialists, and the head engineer in particular had had considerable Platformer experience. He helped establish key operating controls, especially those relating to catalyst protection and Platformer severity. All of the U. O. P. engineers had worthwhile suggestions and a harmonious relationship developed between them and the Union Oil personnel as they worked together on shift.

4. Unifiner Specialist. Brought from Union Oil's Research department, this man supplied technical knowledge and startup assistance for the Unifiner. As is frequently the case in commercial units, the feed to the unit was different from design.

At the time of the startup it was necessary for the Unifiner to remove three to four times as much nitrogen as had been originally planned, yet the Unifiner readily accomplished this by producing a nitrogen-free feed to the Platformer. Union's Unifiner specialist helped establish the necessary operating controls that optimized the pretreatment of the Platformer feed and provided adequate protection of the Unifiner catalyst.

5. Instrument Specialist. This man had spent many years in a supervisory capacity in the refinery instrument department. He worked part time on this project during the early design stages and during the construction phase as he inspected all instrumentation facilities while they were being installed. As construction neared completion, however, it became a full time job as he directed the checking, servicing and placing into operation of all instruments.

Those who have had experience starting up a modern plant will probably agree that some of the more serious problems can be caused by instrumentation malfunction. Due principally to the efforts of this capable instrument specialist, the units went on stream with very few instrumentation problems.

6. Pump and Compressor Specialist. Here we used one of the regular refinery machine shop foremen who was placed on this assignment full time when this type of equipment began arriving on the job. He worked with contractors' personnel observing the installation of all pumps, turbines, motors, compressors, fans, etc. He corrected or revised items to comply with refinery experience when it was easy and inexpensive to do so. His efforts paid dividends in the form of trouble-free operation of the pumps and compressors, not only during the startup but also during subsequent operation.

7. Electrical Specialist. This man was necessary on this project due to the complexity of the electrical facilities. The alarm and protection system has numerous automatic shutdown devices which combine instrumentation and electrical functions. This specialist also worked part time during the design and construction stages and full time during the startup on the miscellaneous electrical problems that occurred.

8. Operator Trainer. This assignment was filled by a head operator from the Oleum Unifiner-Platformer who was loaned to the Los Angeles refinery for six weeks. He had operated the Oleum units for two and one-half years including the initial startup. He assisted in the classroom training of the operators and spent much time at the units giving on-the-job training. He also gave considerable assistance in analyzing operating and mechanical problems.

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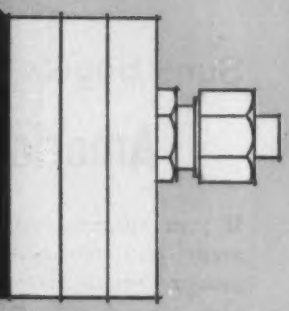

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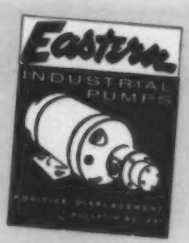

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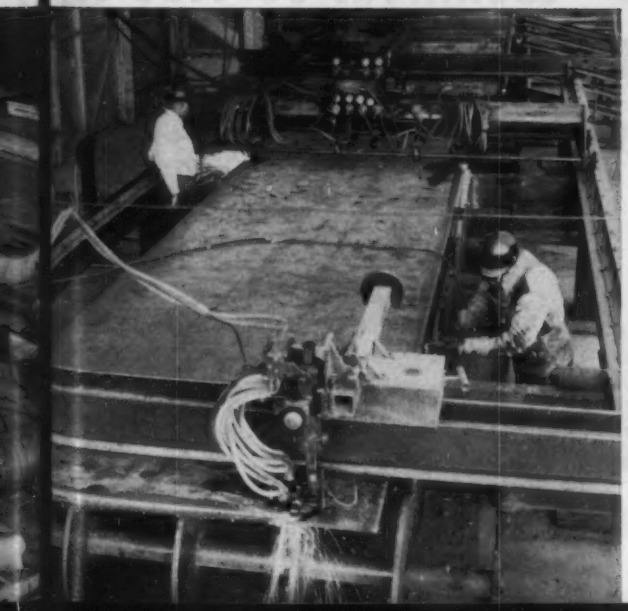

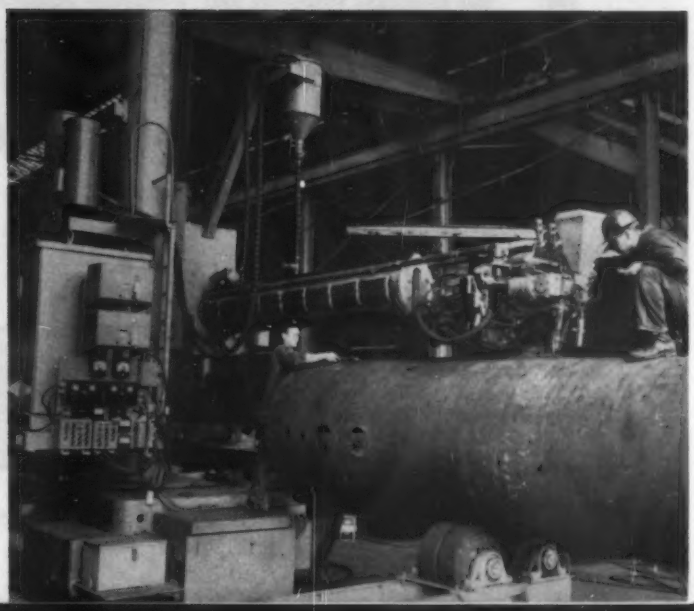

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His experience was a steadying influence during upsets, as he proved to be a very valuable addition to the startup organization.

9. Assistant Shift Engineer. Use of the assistant shift engineer assignment had a dual purpose. It gave valuable operating experience to four young engineers, and provided assistance to the more senior shift engineers in handling technical problems, plotting data, writing operating procedures, making process calculations, etc. Startups of new plants are infrequent, therefore, we utilized this opportunity to permit younger engineers to participate.

NORMAL OPERATING ASSIGNMENTS

Normal operator staffing as shown by the shaded areas on the chart is four per shift; however, two extra operators per shift were provided during startup. All operators had transferred from other departments within the refinery and their experience varied from two to 28 years. As a group, their ability was considerably above average and this contributed immeasurably to the smoothness of the startup and the ensuing operations.

1. Operating Department Maintenance Foreman. This assignment was filled by an operating foreman who now spends full time working on maintenance and mechanical problems. He is the liaison man between the operating and maintenance departments for routine repair work and for major turnaround work. Experience in other operating departments has shown that such an assignment is justified on the basis of reduced maintenance costs and less off-stream time due to mechanical problems. These are not the only units for which he is responsible, but during the startup he worked almost full time at the Unifiner-Platformer.

2. Shift Foreman and Shift Engineer. These responsibilities represent another unique feature of this organization. The shift foreman was the senior line supervisor on duty and, as such, was directly responsible for the personnel and the overall operations of the units. The shift engineer was officially a staff assignment having the primary responsibility of being a technical adviser to the shift foreman.

Actually, the two men on each shift worked together as a team to combine the technical and organizational abilities of the engineer with the experience and work directional abilities of the foreman. The four engineers, having an average refinery experience of about eight years, also worked with their crews and upgraded their abilities and knowledge of the entire process, including such things as the process chemical reactions.

After the units were operating satisfactorily, three of the engineers returned to their regular assignments and one still remains as the staff engineer for these units.

The four shift foremen were men who had progressed through the operator ranks to foreman several years previously. They had an average refinery experience of 24 years. In previous years the foremen had usually played minor roles in startups. However, during the early de-

About the Author

E. P. Barnett is supervisor of crude and reforming. Union Oil Co. of Calif.'s Los Angeles refinery, where he is responsible for the operation of two crude units, a vacuum unit, and a Unifiner-Platformer. Holder of a B.S. degree in chemical engineering from Louisiana State University, and a registered professional engineer in California, Barnett has been with Union Oil 13 years. He has been in technical service, personnel and operations. Before his present assignment, he supervised startup of a Unifiner-Platformer and was in charge of bulk transfer, which included tankage, gasoline blending and bulk shipments.

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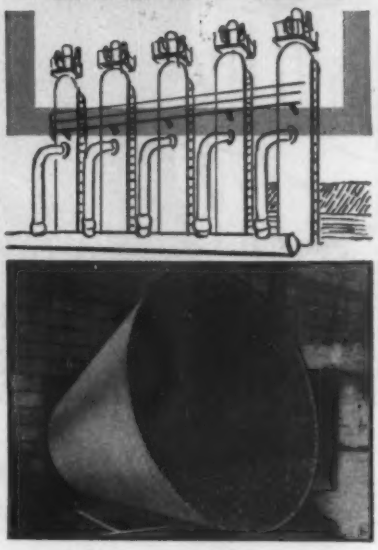

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velopment of these organization plans, we decided to put the foremen in charge of the operations from the beginning.

We concluded that if capable foremen are selected to begin with, and if they are given thorough training and preparation, three important accomplishments result:

(1) The most capable men from an overall standpoint will be in charge of the initial operation

(2) There will be no interim period when the units are supervised by inexperienced people

(3) The irreplaceable knowledge and experience gained during startup will be retained in the refinery supervisory force.

These same shift foremen still supervise the activities of the Unifiner-Platformer, although it is no longer full time, as they also are responsible for other units. But even now, two years later, there are occasions when an operating problem is quickly solved as a result of something one of the shift foremen learned during the startup.

Onstream. So far very little has been said about the actual startup and the subsequent operations. Although the majority of the work lies in the preparations, the big moment comes when the unit is put on the line for the first time. This is always an exciting climax to the months of preparation.

This startup was smooth and progressed ahead of schedule. The timetable had allowed several days for mechanical problems and operational difficulties and, although some were encountered, only about half the estimated time was required. As in any first operation, there were numerous problems, but none of these proved to be serious.

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IN VIEW of the very good record of the petroleum industry, it is natural to inquire why the subject of explosions in petroleum processes should be discussed. Our reasons are twofold. First, we believe that petroleum technology is changing rapidly, new hazards are being introduced, and some older hazards have been eliminated. Second, a careful analysis of a potentially hazardous situation can very often lead to modifications of procedure or equipment that can greatly reduce the hazard.

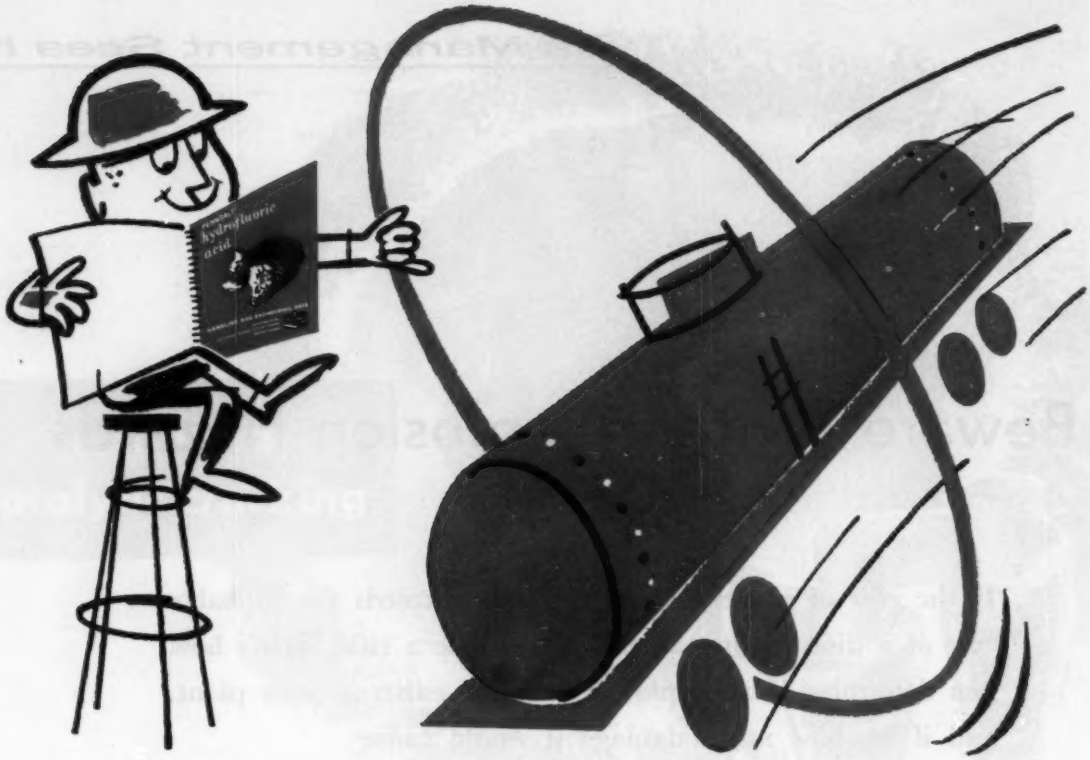
A brief outline of methods of hazards analysis, therefore, appears to be in order. Furthermore, contrary to common belief, an analysis of hazards does not necessarily lead to the expenditure of more money. In fact, a careful study of a problem often results in the elimination of expenditures for certain features that at first seem necessary.

Economic Considerations. Most industrial activities involve the element of risk, of possible loss of capital equipment from collision, fire or explosion. Factors other than economics enter into the decision of how much can be expended to prevent disasters. However, the economics of a disaster situation is an important consideration which can be handled by balancing the probable cost of a potential disaster against the cost of its prevention. If the former is substantially greater than the latter, expenditures for prevention are indicated. If, however, cost of prevention outweighs the probable cost of a potential disaster, it may be good business to take the risk.

The probable cost of a potential disaster is the product of two factors: the "chance of occurrence" and the "probable damage." For explosions, a very rough estimate of probable damage can be made by calculating the available energy of the explosion, estimating the probable efficiency with which the energy can be used for destructive purposes, and determining a probable zone of damage around the site of the explosion.

Statistics Available. Estimating the "chance of occurrence" is less direct. If the situation is a historical one, use statistics. For example, what is the chance of a large storage tank failing by conditions incident to low atmospheric temperatures? Because there are over 150,000 tank years of experience, there exists a statistically expected chance of failure of about one in 15,000 tank years from conditions characterized by low ambient temperatures.[1]

In most refinery situations, far fewer cases are available. Here statistically derived results are accordingly less reliable and must be tempered with judgment. In some cases statistical data from similar or analogous situ-



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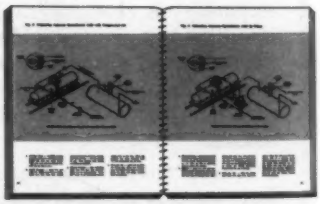

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ations are available and can be employed profitably. Often only very approximate data suffice.

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$$\$25{,}000 = \$1{,}000{,}000 \times \text{Chance of Occurrence (per lifetime of sphere)}$$

or Chance of Occurrence = 1/40 at breakeven.

If the sphere has an estimated useful life of 20 years, the breakeven chance of occurrence per year then becomes 1/800. The problem then is reduced to that of estimating whether the actual chances are greater or less than 1/800 years.

Theoretically it should be possible to calculate the probability of occurrence, but at present this appears to be impractical.

Estimating "Probable Damage." Here two principal questions are to be answered. Namely, does a potentially explosive situation exist and if so, what is its magnitude? The greater part of this article discusses different possible explosive situations. At this time we wish to indicate very briefly how the magnitude of these may be estimated and how the probable damage is related.

When an explosive mixture exists, it has a certain total heat content. Of this total heat, only a certain portion is available for destructive work, namely, that which can be extracted from the heated products of combustion as their pressure drops from the maximum attained in the given situation to atmospheric pressure. However, explosions are not very efficient processes and only a certain portion of this energy is available, usually of the order of 20 percent or less.[2,3]

A number of examples will serve to illustrate the above principles. Consider the three following explosive situations:

1. Cone roof tank containing 10^5 scf of an air-hydrocarbon mixture at atmospheric conditions.
2. A spheroid containing 10^5 scf of same mixture at atmospheric conditions.
3. A butane sphere having a vapor space one-fourth the size as above spheroid but containing the same mixture at 45 psi.

Now the thermal energy available from explosion will be the same in all three cases, but the destructive energy delivered to accelerated fragments in the three cases will be approximately in the ratio of 1:35:75! The main point here is that in case 1 the tank roof lifts at a very low pressure (assumed to be 2.5 psi in this case) and most of the energy from the explosion is exhausted harmlessly into the air. For the same reason, the roughly equivalent potential energy in case 3 results in about twice the destructive work of that in case 2 because the sphere bursts at 350 psi whereas the spheroid was assumed to burst at 60 psi.

Dollars and Chance. Now, there is no direct relationship between destructive potential and dollar value of damage. The latter, of course, depends upon the location of vulnerable objects in the vicinity of the explosion. Furthermore, when an explosion takes place, the element of chance plays an important part in determining the extent of the damage. Consequently, even if one knows the location and value of all properties surrounding a potential explosion there is no direct way of calculating the probable damage.

Where statistical information is available, such as that generated in World War II, this can be usefully employed in the present connection. For example, the three situations described can be reduced to their TNT bomb equivalents, which would be approximately 0.05, 1.75 and 3.5 tons of TNT, respectively.

Another way of arriving at an estimate of probable damage is to use the so-called Monte Carlo method,[4] which is a very elegant way of generating synthetic statistics where actual ones do not exist. In this method the sequence of events immediately following an explosion is broken into a number of stages, and at each stage probabilities are assigned to the different possible turns of events. The statistics generated then take the form of a probability curve with cost of damage plotted against chance of occurrence. The model can, of course, be made as simple or as elegant as the situation demands.

In summary, estimation of probable damage is not an exact science, being a composite of science, statistics and judgment. However, if the work is thoughtfully done, it can be surprisingly accurate.

Problem of Containment. Many processes employ oxygen and hydrocarbons together, and for some of these the probability of an explosive mixture is relatively high. In such cases it is natural to inquire whether it is possible to construct the containing vessels and piping strong enough to hold possible explosions. In attempting to design equipment in such a manner, we find a number of discomforting facts.

First, even though the maximum explosive pressure may be calculated, this cannot always be used to determine the necessary strength of the equipment as is done in a static case. If the force is rapidly applied, it exerts a dynamic load as well as a static one, and the sum of these two can be twice as great as a static load alone. Furthermore, under the impact of sudden loading the steel may not exhibit its usual ductility, but may fail at the end of its elastic limit, particularly if any stress concentration exists. This reduces its effective strength by a factor of approximately two. Combining these two

effects, the containing vessel would have to be four times as strong as calculated for static pressure.

Another factor of even greater importance is that hydrocarbon-air mixtures can detonate under certain conditions. If detonation occurs, the peak pressures will be about four times as great as those calculated for "normal" explosions. In addition, detonative pressures are subject to multiplication upon reflection from vessel walls by a factor of two or considerably more. Putting this all together, the steel would have to be at minimum 32 times as strong as would be calculated for static conditions.

Conditions promoting detonations of air-hydrocarbon mixtures are long unobstructed vessels and turbulent gas conditions.[5] Avoidance of both of these is important where explosive mixtures can exist.

In summary, a number of factors, all unfavorable, must be considered in designing equipment to contain explosions of hydrocarbon-air mixtures.

Storage Problems. Cone roof tanks are often used for storing materials which produce explosive mixtures at ambient temperatures (see Figure 1). This being the case, you may logically ask: Why be concerned about the possible existence of explosive mixtures elsewhere in refining operations?

The reason is not that tanks do not blow up (e.g., for lack of ignition sources), because they occasionally do. It is rather, as indicated earlier, that when a tank explodes most of the available energy is exhausted into the air in a non-destructive manner. The damage to surrounding areas is usually limited at maximum to about two tank diameters, providing the shell remains intact. Hence such tankage should be located at least this far from personnel or vulnerable equipment.

If the explosion should occur in cold weather, there is a good chance that the shell also might fail, creating the added problem of a wave-like discharge of the contained liquids which may easily engulf the usual dikes. Incidentally, for a 50 feet high tank, three-quarters filled, the energy released in a wave action by the stored liquid will be about 50 times that given to the roof from an explosion in the vapor space. Possible sources of ignition in tankage include pyrophoric iron sulfide, static electricity from splash filling or agitation of water bottoms, and lightning if open vents are present.

Spheroids are generally used for stocks having vapor pressures sufficiently high that the vapor space is rich even in quite cold weather (Figure 1). However, they are sometimes used in services where the vapor pressure is not controlled. When this is the case, the situation is much the same as it is with atmospheric storage, with the important difference that the consequences of an explosion for the spheroid are considerably greater.

A second possibility exists which is non-existent in the case of atmospheric storage; namely, that of trapping air in a partially filled spheroid and compressing the air by subsequent filling. This is a mechanism, explained later in greater detail, whereby the vapor space can be made to progress from a safe to a potentially dangerous condition (see Figure 2).

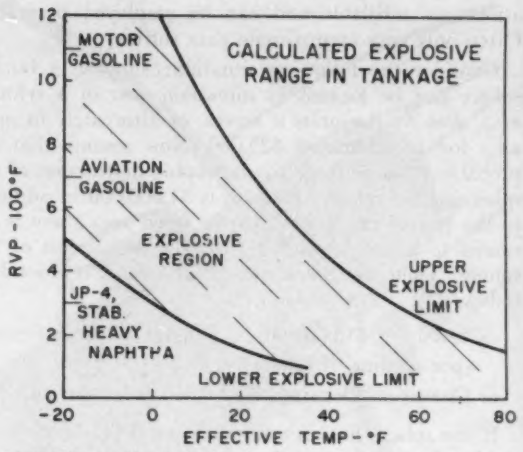


FIGURE 1—Explosive limits for some common petroleum materials.

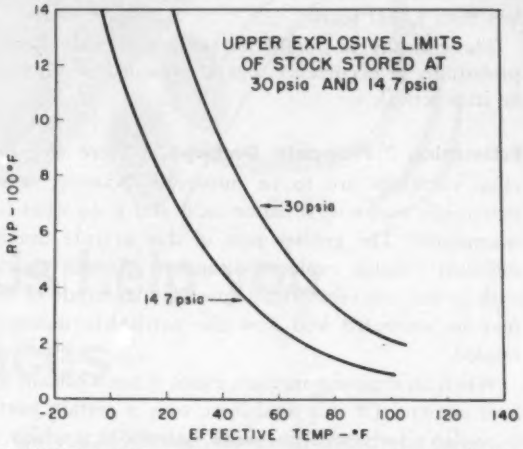
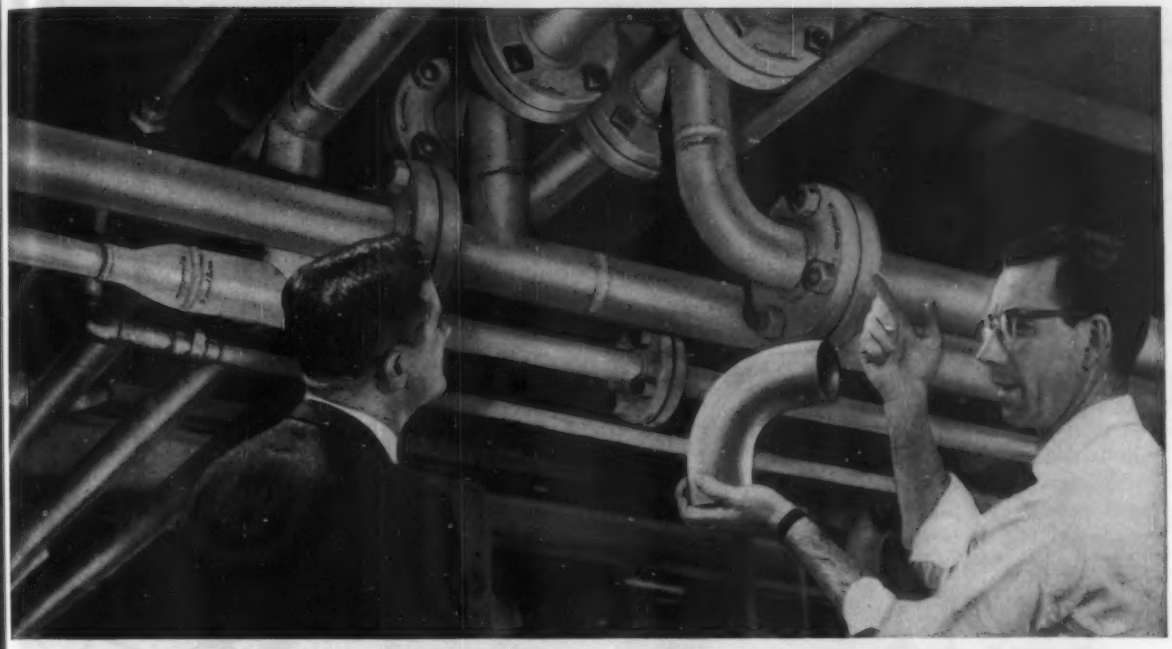


FIGURE 2—Effect of storage pressure on upper explosive limit.

If the vapor pressure of the stored material is known, this situation can be avoided by not allowing the storage pressure to exceed the known vapor pressure by more than a few pounds.

Considering Butane. The storage of butane presents an interesting situation.[6] Usually the vapor space in a butane sphere is far too rich to cause concern, and also the incidence of explosions in pressurized storage is reassuringly low. Nevertheless, as indicated earlier, the consequences of an explosion in a butane sphere can be quite serious.

It is accordingly important to examine under what conditions, if any, explosive mixtures can form in butane spheres. It is obvious that if butane is pumped into an unpurged sphere, an explosive mixture will exist during the early stages of filling. In addition, air or oxygen may also be carried into working spheres in solution in the butane. Upon storage in the tank these gases are re-



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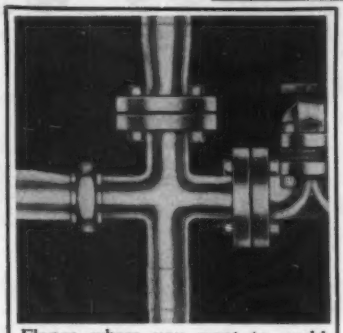

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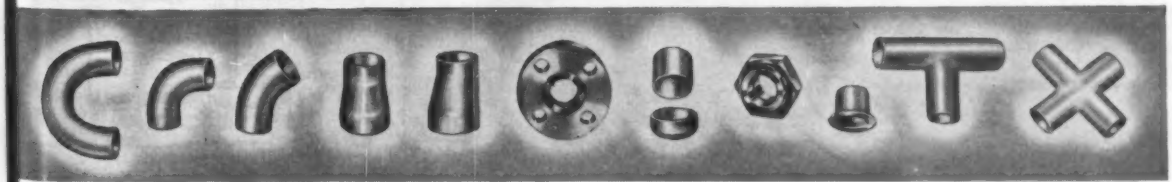

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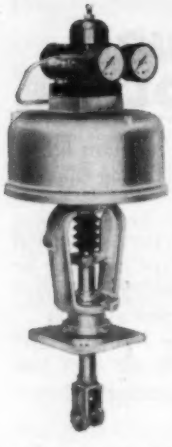

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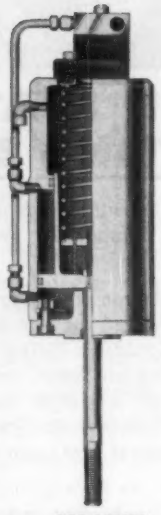

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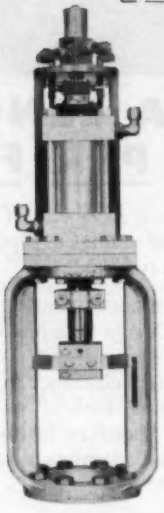

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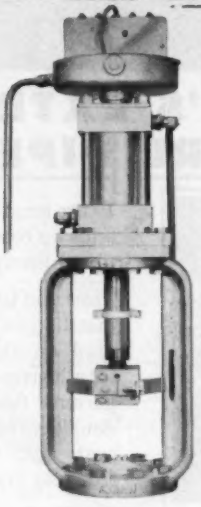

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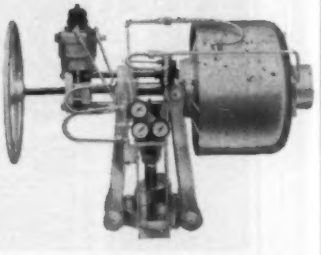

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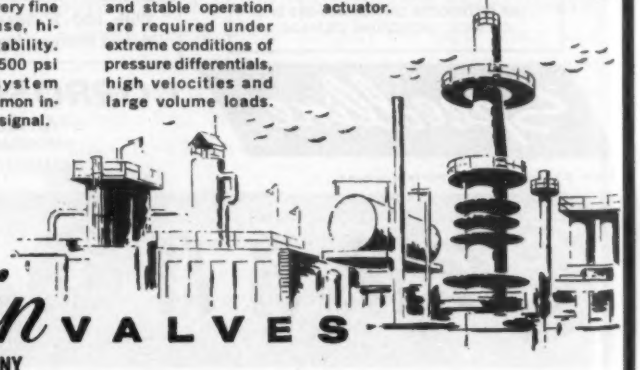

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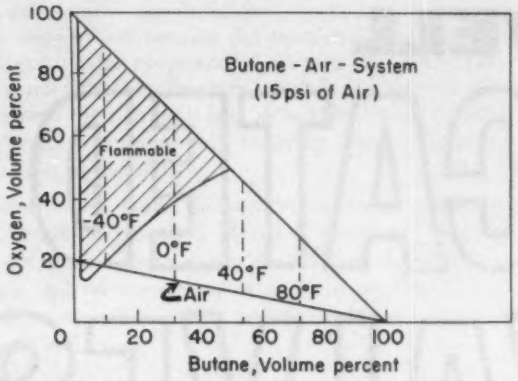

FIGURE 3—Temperature effect upon composition of vapor space in butane sphere.

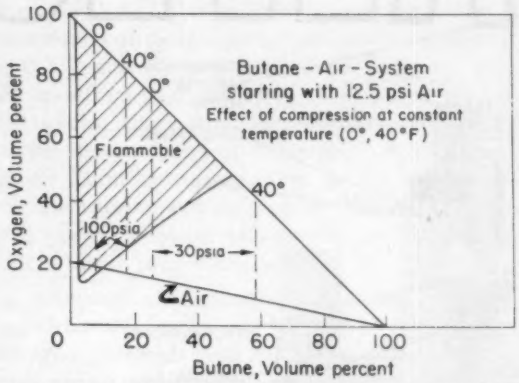

FIGURE 4—Effect of liquid filling upon composition of vapor space in butane sphere.

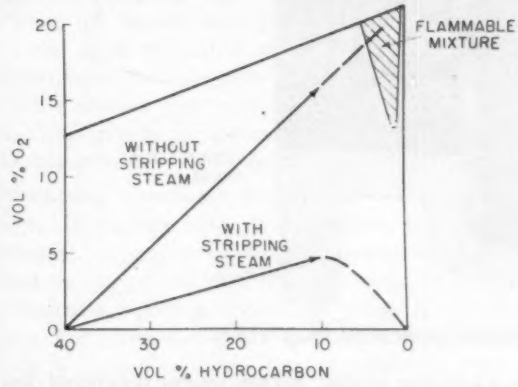

FIGURE 5—Composition of vapor space in vacuum tower after failure of ejector.

leased to the vapor space until this comes into equilibrium with the liquid surface. Because air and oxygen are more volatile than butane, equilibrium favors a much higher concentration of these gases in the vapor than in the liquid.

If the temperature is sufficiently low and if the vapor space is compressed by filling with liquid, it is possible to create an explosive mixture, as illustrated below. Air can also enter butane spheres which are equipped with vacuum breaker valves which open to the atmosphere when the pressure goes subatmospheric. Such valves are sometimes installed on spheres which are not designed to withstand full vacuum. Trucks are known sometimes to unload their LPG cargoes with air pressure. While this may be safely done, if the temperature is not too cold, butanes handled in this manner can later become dangerous because of the dissolved oxygen which they contain.

Figure 3 shows the explosive limits for the butane-oxygen-nitrogen system. In this type of diagram, butane and oxygen are read directly and nitrogen is the difference between the sum of these and 100 percent. As an example, compositions at four different temperatures are shown for butane at its vapor pressure with 15 psi of air (intersections of vertical lines and the air line). Notice that in the present case the temperature would have to drop below —40° F for an explosive mixture to exist.

Figure 4 shows another hypothetical situation. Here a 12.5 psi partial pressure of air is assumed to be initially present in a butane sphere. The results of compressing the vapor pace by liquid filling are shown at 40° F and 0° F. This compression results in a higher partial pressure for non-condensable gases like air since they do not go into solution easily.

Meanwhile, the butane partial pressure remains constant at its saturation value. At 40° F neither compression to 30 psia or 100 psia produces a flammable mixture, whereas at 0° F compression to 30 psia does not and compression to 100 psia does. While this situation could not occur in most geographic locations, it could take place in the normal course of events in a northern latitude.

There is, of course, no certainty that ignition will occur, but pyrophoric iron sulfide or static electricity from liquid agitation could ignite the vapors. The considerable destructive potential in this situation, as indicated in Figure 4, warrants careful attention to avoid getting air in butane spheres in cold weather.

In summary, atmospheric tankage often contains explosive mixtures, and therefore, sometimes explode. These, however, do not have great destructive potential. Pressurized storage does not contain explosive mixtures as frequently, but the consequences of explosions in these are considerably greater.

Operating under Vacuum. Processes which operate at subatmospheric pressure present a special problem, namely, that caused by sudden spoilage of vacuum with atmospheric air. Consider the vacuum distillation tower. If the driving steam to the ejectors should fail, atmospheric air will back into the tower through the ejector discharge. Two different situations will occur according to whether or not the stripping steam supply fails simultaneously.

If the stripping steam supply fails, the tower will go

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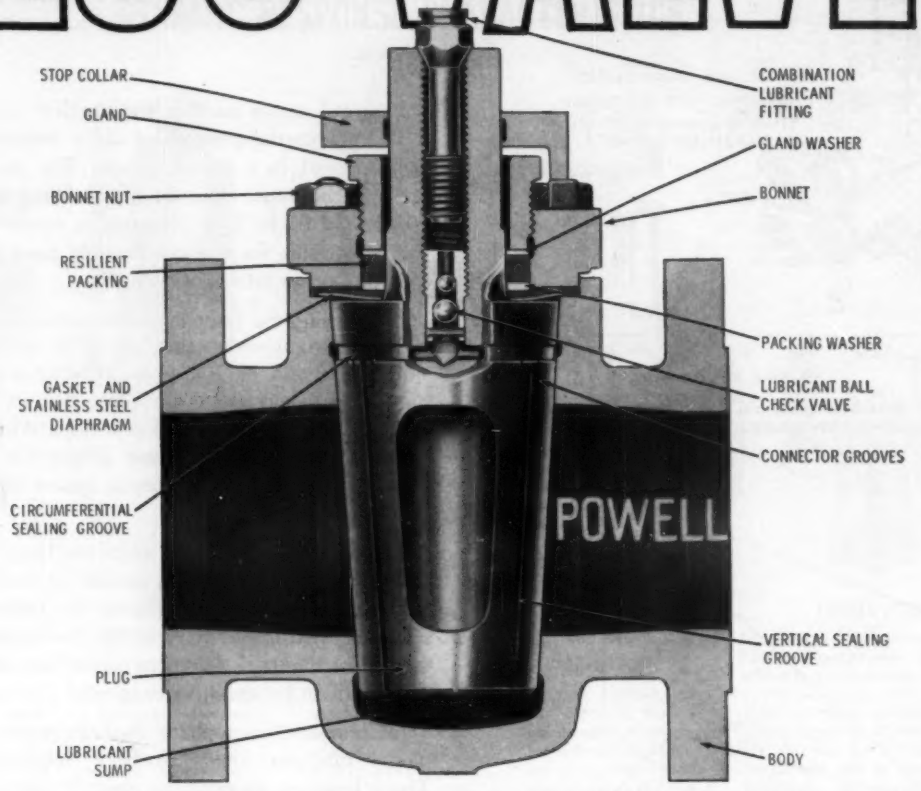

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into an explosive condition quite rapidly. Ignition is almost certain here because the temperature of the oil is high enough for sponstaneous ignition. Extensive damage is not probable, however, because burning will take place near the rich limit and because the tower internals will tend to suppress any tendency toward flame acceleration or detonation.

Nevertheless, costly damage to the tower vessel and its internals is probable. Means of prevention include: an independent steam supply for stripping steam, a barometric seal on the ejector exhaust, or possibly a check valve in the exhaust line which would probably give limited protection.

Solvent Dewaxing Vulnerable. Other vacuum processes are subject to similar hazards. In the solvent dewaxing process a breakage of any one of a number of lines or vessels will place a large part of this system in a hazardous condition with considerable destructive potential. Ignition is not certain, but there are good possibilities from static electricity or from friction generated sparks, either from the hypothesized break or from the moving parts of the process. A rapidly responding alarm system operating on the presence of O_2 in the vacuum system, coupled with the ability to rapidly purge the system with an inert gas, is a possible means of taking care of this problem.

In summary, most vacuum systems are subject to hazard from the inadvertent entry of atmospheric air. Destructive potentials vary in individual cases. Means of prevention usually entail some means of purging which can be rapidly applied in case of an accident.

Processes Using Air. Air is used in refineries in large quantities for catalyst regeneration, in sweetening processes, and as an oxidant in petrochemical processes. In addition, inert gas generators and some heaters use air in such a manner that certain mistakes or failures can lead to potentially dangerous situations. A few typical situations follow.

Sweetening processes employ air or commercial oxygen. If through error of operation or failure of equipment, oxygen is employed in excess of that required by the process and that which can be carried in solution, it is possible to build up pockets of explosive vapors. For example, if the oil flow should stop and the supply of oxygen continue, then an explosive mixture would form at the top of the settler. Chances for ignition are good because agitation of the two phases present in the settler is conducive to the generation of static electricity.

The consequences of an explosion could be serious since the vessels involved are generally designed for moderate pressures and would not be expected to fail before a sizable explosive pressure is generated. Protective measures include a careful tie-in between oil feed and oxygen supply to prevent the situation just described, also the physical arrangement of vessel and piping layout to exclude volumes where vapors can

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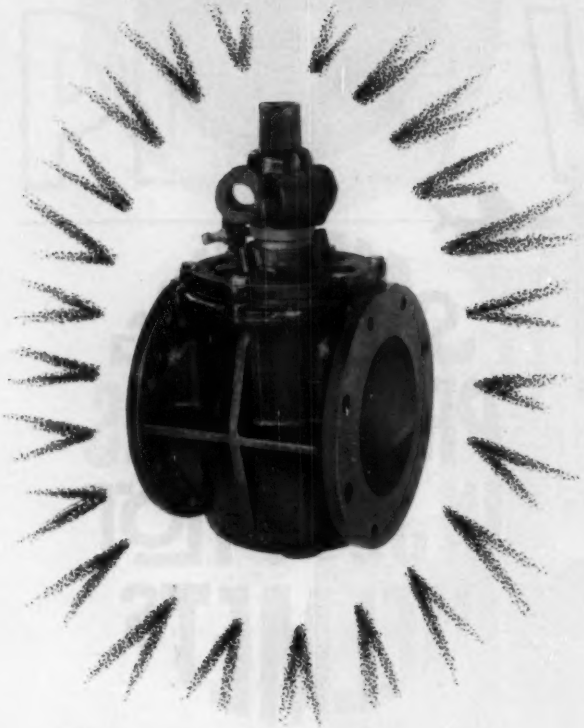

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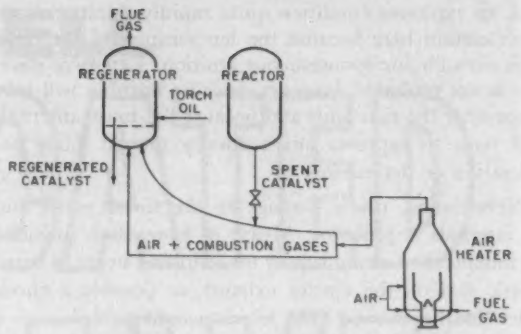

FIGURE 6—In-line heater schematic.

collect. For instance, nozzles for liquid draw-off piping should be located at the highest possible point on each vessel.

Doctor sweetening presents similar hazards which are not always as well recognized as those for copper sweetening, perhaps because doctor sweetening is generally employed with lower vapor pressure stocks at temperatures below their flash point. However, two possibilities for trouble exist.

First, if excessive amounts of hot regenerated doctor solution are allowed to carry over into the treater vessel, this could raise the temperature of the latter above the flash point of the stock and create an explosive mixture in the vapor space of that vessel. Second, if hydrocarbons are allowed to carry through the separator in sufficient quantity to the regenerator vessel, they can vaporize there and create an exploive mixture. Accordingly, this is a process which must be operated carefully by operators who understand the possible consequences of deviations from the normal situation.

Indirect Use of Air. Many processes which do not employ air directly use air indirectly for heating or inert gas generation. The hazards here are apparently fairly well known since the incidence of explosions from these sources is low. However, some of these devices deliver their products of combustion into large vessels of substantial construction where detonation is possible and the consequence of an explosion could be a disaster of major proportions. Hence it is very important that the hazards associated with their operation be well understood.

The in-line heater shown in Figure 6 is representative of this type of device. Here, as in many similar devices, a simple flame-out does not create a dangerous condition since the normal volume of by-pass air is sufficient to maintain a safely lean mixture. Furthermore, devices of this type are invariably equipped with flame-out alarms and fuel cut-off controls. However, if a flame-out should be caused by a failure of the main air supply and the gas feed should not be shut off (two simultaneous failures implied), the vessels downstream from

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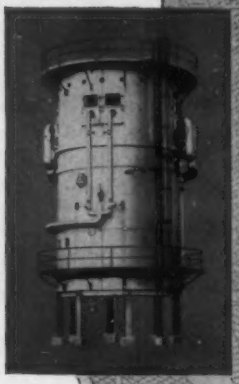

Since its introduction ten years ago, the Chemico *gas reform furnace* has often proved the most efficient and economical first step in the production of ammonia, methanol and high purity hydrogen from natural gas. The unique design of the Chemico *gas reform furnace* eliminates thermal expansion problems, assures easy control during operation and requires minimum maintenance.

Now there are more than 60 furnaces in operation, and another 10 are in the design or construction stage. These units range in capacity from 50,000 to 8,000,000 standard cubic feet per day of hydrogen plus carbon monoxide. For any process which requires hydrogen, the Chemico *gas reform furnace* may well prove the most economical means of obtaining the necessary quantities. Write to Chemico for further information.

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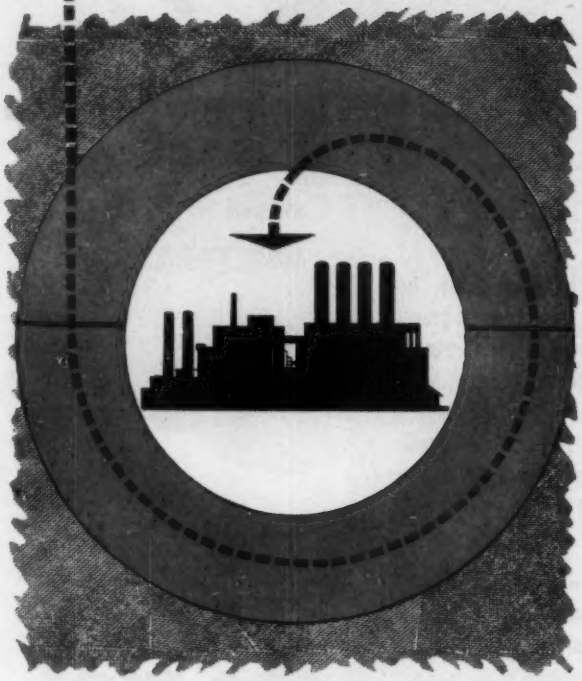
High Thermal efficiency means Darlington Insulation



H18

Year after year the Central Electricity Generating Board's list of power stations with the highest operating efficiencies includes a majority of stations where the efficiency is guarded by Darlington Insulation. In the 1957 list, for example, the top four stations are Darlington insulated. Coincidence? Not a bit of it! Just skill and years of experience, plus careful specifications and the right materials. It's the Darlington Insulation Company's job to help maintain high thermal efficiencies, and they do it very well.

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and branch offices at London, Birmingham, Bolton, Bristol, Cardiff, Glasgow, Leicester and Sheffield.

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the heater will quickly become filled with an explosive mixture.

If under these conditions reignition should be attempted, a disaster of major proportions could follow since the dimensions of the regenerator vessel would be conducive to detonation, and it is unlikely that the vessel would fail before the onset of a detonation. Here the "chance of occurrence" is admittedly not great, but the "probable damage" is great enough that no chances whatsoever should be taken.

In summary, many processes use air or oxygen directly or indirectly. In a number of these, certain failures can lead to the formation of explosive mixtures. Safe operation of these processes requires that the operators be thoroughly familiar with the consequences of improper operation due to errors of manipulation or failure of equipment. In some cases special instrumentation is indicated.

Flare Stacks. The usual refinery flare stack takes care of hydrocarbon gases and there is only moderate concern and probably little danger from flashbacks which can occur after a perior of low gas flow. During a period of low gas flow atmospheric air can diffuse downward into the stack and create an explosive mixture which may be later ignited by progression toward the flare.

The advent of refinery processes which produce by-product gas high in hydrogen content presents a new problem. First of all, whereas an explosive hydrocarbon-air mixture would probably fill only a small section of the stack, being rich below and lean above, the hydrogen-rich gas could fill a large length of the stack because of the much wider explosive limits for hydrogen.

Furthermore, whereas ignition of a hydrocarbon-air mixture would probably do very little damage, it is quite possible that the hydrogen-air mixture would detonate even in the open-ended stack.[4] Such detonation could cause considerable damage by blowing the stack apart in a number of places. Assurance of an adequate flow of gas up the stack at all times to prevent diffusion of air downwards is one way of preventing this type of accident.

Conclusion: 1. Factors other than economics, such as possible loss of life, will often determine whether an expenditure should be made to avert a possible accident, but this does not deny the importance of economics in arriving at a decision.

2. It is very difficult, and perhaps prohibitively expensive, in most cases, to design process equipment which can contain explosions.

3. Many refining operations can lead to explosions. It is most important that all concerned with the design and operation of refining units be thoroughly familiar with specific failures of equipment or of operation which can possibly lead to explosions. It is equally important that pre-arranged plans are made for handling such failures before explosions occur.

4. Experience in the analysis of many suspected hazard situations in line with the above has led the

FOAMGLAS® insulation on these methyl ethyl ketone filters cuts insulation maintenance costs

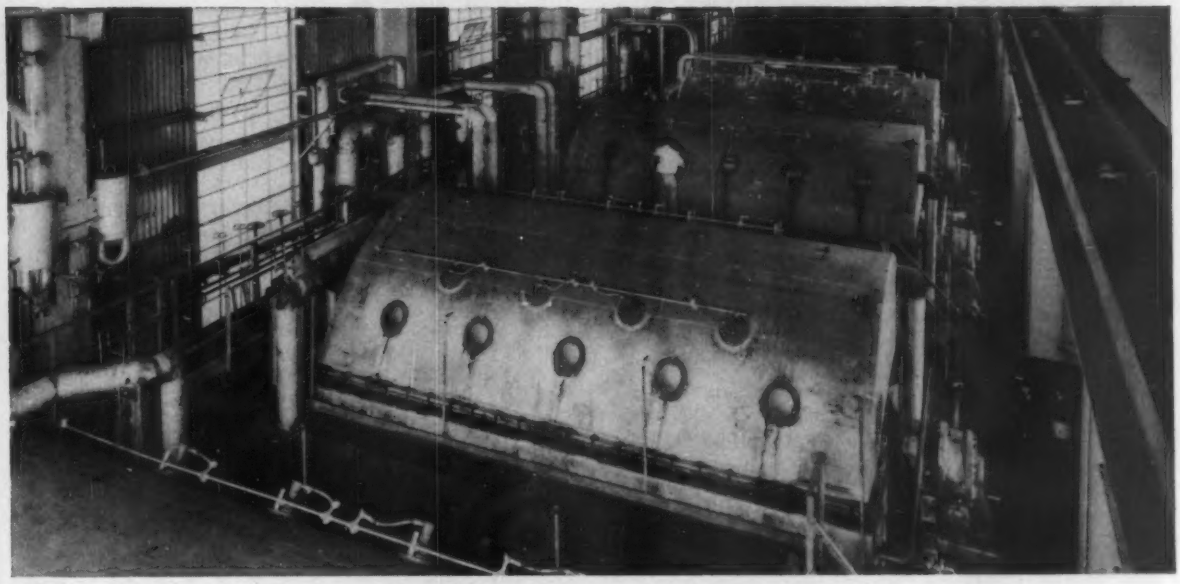
A saving in ketone filter insulation maintenance at the Beaumont, Texas, refinery of Mobil Oil Co. is made possible by the many features of FOAMGLAS insulation.

Different operating temperatures for different jobs subject this insulation to constant strain. Filters are chilled anywhere from 40°F. to 0°F., often resulting in ice formation from condensed water vapor. This has damaged insulation materials previously used. But water vapor cannot penetrate the sealed glass cells of FOAMGLAS. There's no crushing "freeze-thaw" cycle within the FOAMGLAS as there is with organic insulations.

Insulation loses much of its effectiveness when it is waterlogged. Not FOAMGLAS, however. Other insulations tried had required frequent maintenance, while FOAMGLAS remains effective for the six years it has been in use. Extremely easy to work with, easy to cut and shape with any sharp tool, FOAMGLAS is impervious to acid . . . even ketone.

Why not find out more about FOAMGLAS insulation? Write for a sample and for information on our two newest products; FOAMGLAS Stay-Dry Pipe Insulation, and new 1¾" FOAMGLAS Roof Insulation. Pittsburgh Corning Corporation, Department Z-99, One Gateway Center, Pittsburgh 22, Pennsylvania. In Canada: 3333 Cavendish Boulevard, Montreal, Quebec.

Pittsburgh Corning offers a complete line of mastics, tank coatings and other accessory materials specifically designed for use with FOAMGLAS.



The three filters shown above are typical of filters insulated with FOAMGLAS. These 21' by 11' diameter filters, insulated with layers of 2" and 3" FOAMGLAS, separate wax from oil. The refinery, largest in the Mobil system, has a rated capacity of 220,000 barrels per day.

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Vise base, that overhangs front legs for clear tool swing, has hanger slots for tools, 3-size pipe bender, rear pipe rest and adjustable ceiling brace screw. Folding legs and integral tray set up easily and lock in position for rigid work base. Snap chain holds folded legs closed for easy carrying . . . no loose parts. Rubber grommets in tristand feet prevent creeping. See and try this more-for-your-money RIDGID Top Screw Chain Vise at your Supply House!

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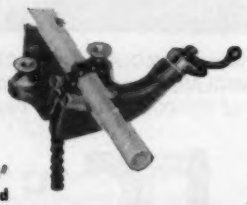

The Ridge Tool Company, Elyria, Ohio, U.S.A.

authors to the conviction that savings resulting from elimination of unnecessary items occur as frequently as do expenditures for added safety.

Originally presented before the World Petroleum Congress, New York, June, 1959.

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About the Authors

Jacobs

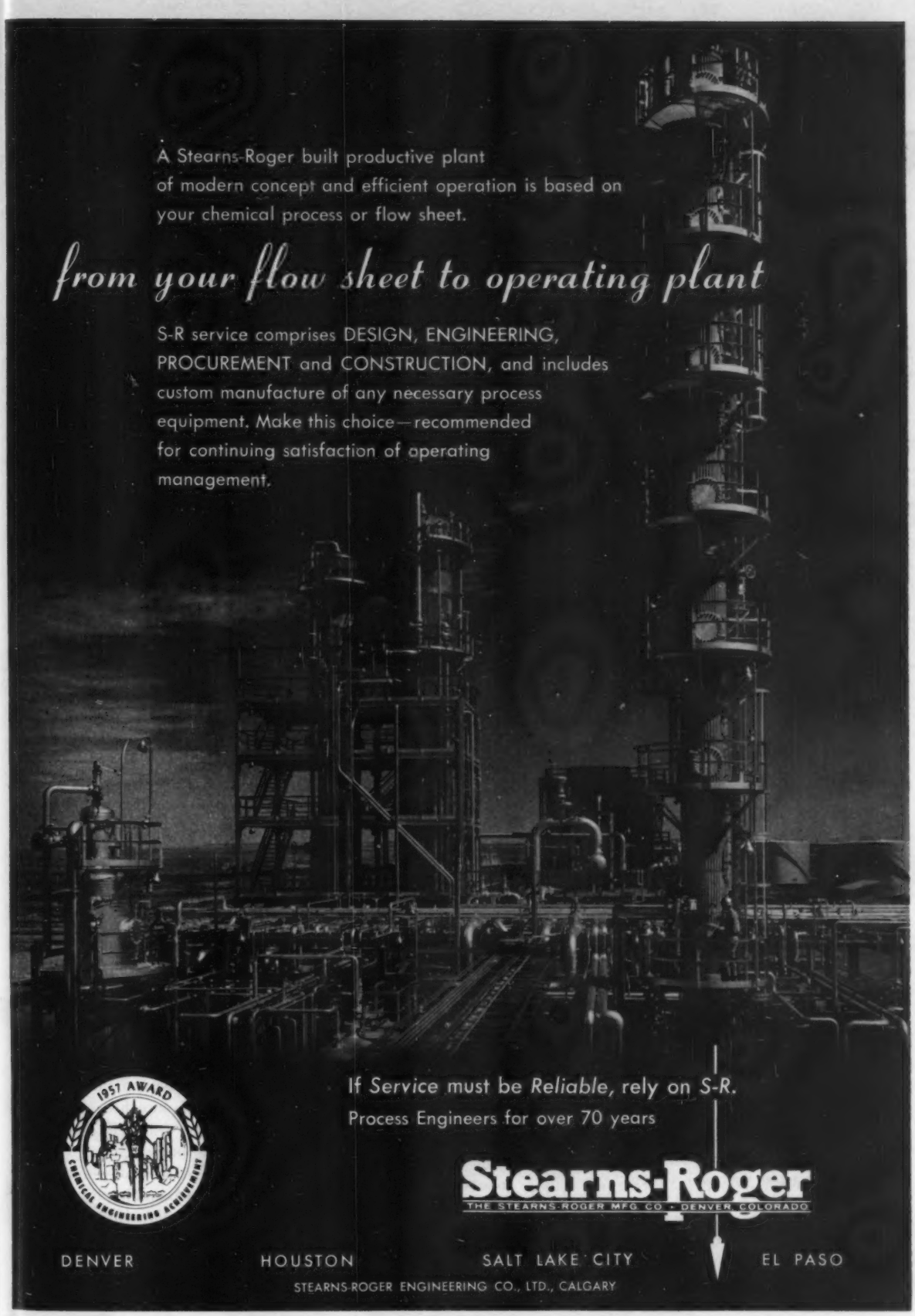
Dr. R. B. Jacobs, is manager, Engineering Research Department, Standard Oil Co. (Indiana), Whiting, Ind. He holds B.S. and Ph.D. degrees in physics from California Institute of Technology. Dr. Jacobs has been with Harvard University as a national research fellow and instructor, with M.I.T. as a Lalor and research associate, with National Research Council as assistant executive secretary, with Kellex Corp. as head of vacuum engineering, and with Distillation Products Co. as head of physics. He has held several supervisory engineering positions since joining Standard in 1947.

Blunck

Dr. F. H. Blunck is manager of unit operating procedures, Standard Oil Co. (Indiana), Chicago. He has a B.S. degree in chemistry from the University of Illinois and a Ph.D. degree in chemistry from Northwestern University. While in military service he was with the Chemical Warfare Service. With Standard of Indiana since 1936, he has held a number of engineering and administrative positions at the Whiting refinery, Chicago general office, and Wood River, Ill., refinery.

Scheineman

F. W. Scheineman is director of engineering, Standard Oil Co. (Indiana). He has a B.S. degree in civil engineering from the University of Illinois. Before joining Standard in 1926, he was with American Bridge Co. and Illinois Central Railroad. He has held key engineering and administrative positions in Whiting refinery's Engineering Department and in the general office, Chicago. He has been director of engineering since 1957.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Which Man Should You Promote?

Here are some of the points you should take into consideration when faced with that tough decision of which man to promote

Ernest W. Fair
Boulder, Colorado

SOMETIMES AVAILABLE promotions are obvious but more often the choice involves some detailed considerations where a number of apparently equal employes are available. Making certain that the right man is promoted is more essential than ever before as no executive or superintendent can ever afford to overlook meritorious individuals. There are just not enough good men available to risk uncertainties in making such a selection.

Here, from careful study of selection methods used by more than a score of executives, are the major considerations which may well be applied to such individuals in determination of who shall receive each such promotion.

These, plus others pertinent to the individual job, can be listed in a "rating chart" which will always make such selection easier and give us greater assurance we are always picking the right individual for the job.

1. Does he keep the quality of his work exceptionally high every working day? When promotions are in the offing, many workers will suddenly become very quality conscious. What each individual has done in the past as well as his present work performance must be taken into account. The man whose more recent performance is unusual will in all likelihood drop back into old routines once the promotion has been obtained. The one who keeps standards high as a matter of work routine will carry through into the new job.

2. Can he report in clear and understandable terms? This is a basic requirement of good job performance in almost every case for the new job invariably calls for considerable reporting of both an oral and written nature. If no such work has been done by the individual in the past, some tests should be made at this time.

3. Is he continuously improving his own knowledge of the work? The man who will be worth anything in the new job can seldom be one who depends solely on his present knowledge to get the job done. Chances are, promotion involves a job of semi-executive status which will require constant improvement in performance.

4. Does he know what to do in out-of-routine situations without being given detailed instructions? The individual who lacks the ability to handle such problems can hardly be expected to suddenly acquire techniques for dealing with them. Out-of-routine situations occur with great frequency in refinery operations all the way down the line. How well each man has handled these when confronted with them in past work posts is a valuable indicator to his abilities for better spots on the refinery staff.

5. Can he stimulate the work of others around him? Some of us by second nature have this valuable trait. Others, no matter how much they pressure themselves, can never acquire it. It is invariably apparent in any employe's day-to-day working habits. It is most necessary in any "better job" to which he may be possibly assigned through promotion.

6. Is he the type of worker who never shirks the unpleasant parts of job and takes them in stride? The higher a man goes in any organization, the greater number of unpleasant tasks will arise. Therefore, he must have the ability to handle the small problems in his present job before there is any possibility of his being able to tackle them in a new position.

7. Can he keep minor records essential to the new job? Here again some sort of test of an individual's ability along these lines may be necessary as record keeping is seldom a part of most basic jobs. It will, in small or large measure, very likely be a part of the new job. We can hardly take a chance on promoting a man who is incapable of handling this phase of the new job, so if experience is lacking, tests are definitely in order.

8. Does he handle job routines with a minimum of effort? This is another trait of utmost importance as the individual rises higher on the staff, for his effectiveness may largely depend on his ability to quickly and efficiently handle all routines for the new job. More and more of his workday time will be needed to handle new tasks, so the less needed to accomplish standard routines, the more capable such an individual can be.

9. Has he always tried to do just a little more than his job called for? Finding such an individual on the staff in these days is never easy yet it is a factor of extreme importance. The man who does no more than required to hold onto his job, even though handled with efficiency, is not exactly a prime choice for a better job where any unwillingness to put forth maximum effort will affect not only himself but those working under him as well.

10. Has he demonstrated flexibility and is not fixed in his way

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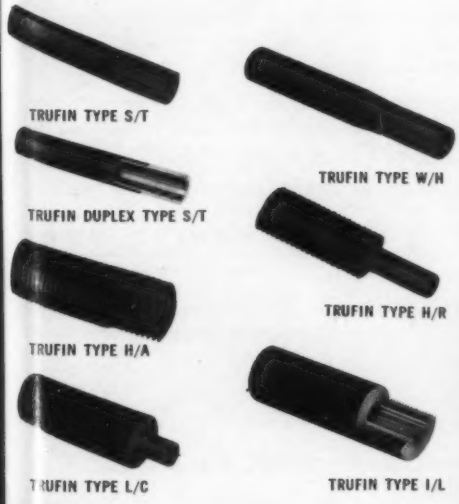

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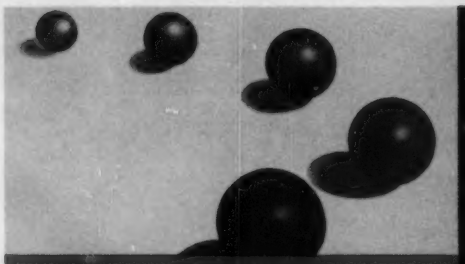

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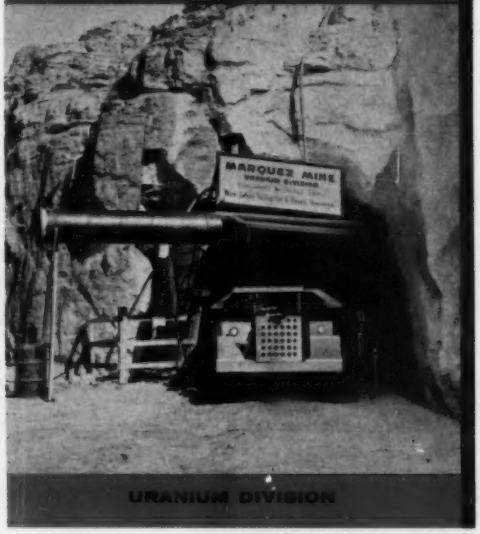

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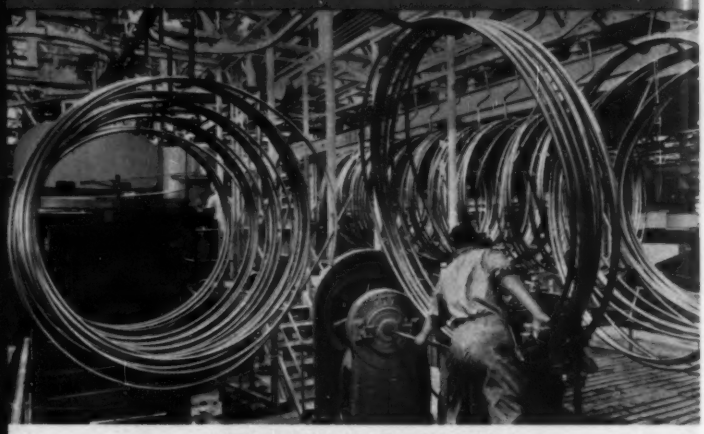

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of doing things? A given individual may be very qualified for the present job he holds without such flexibility yet valueless in the new post for which he is being considered. If the new job requires such flexibility this is an important factor in weighing the merits of available candidates.

11. Has he demonstrated interest in and loyalty to the company? This may not be of importance as long as a man does an acceptable job at lower levels in the business but the higher he climbs on the staff the more important such loyalty becomes.

12. Can he grasp new ideas and new methods? Some of us have this very valuable asset as part of our natures while others never seem able to acquire it no matter how hard they try. Yet it is an absolute must for any man climbing the ladder in a refinery organization.

13. Is he an orderly individual? The man who lacks the ability to be orderly and neat about his work routines is going to be unable to enforce this upon others. The net result may be an entire department over which he has supervision, quickly dropping to his own levels of disorderliness.

14. Has he shown a definite desire for promotion within the company? Management can never expect maximum performance from an individual who has never demonstrated the desire for promotion. It is a requirement where we expect full performance from the new job. The man with no particular desire for promotion is so satisfied in his present job he can be expected to lack the ability to pass along necessary enthusiasm to anyone he may supervise in the new spot.

15. Does he need only the minimum of instruction to handle any task? There is little sense in promoting individuals if 100 percent supervision must still be given them by men higher up the staff ladder. Part of any new job will call for this necessary trait. It should be checked as carefully as any other point.

16. Can he think things out where there are no precedents established? Just about any reasonably intelligent individual can "follow the book" in his job but it takes a little something extra to handle situations which have not been covered by such precedent. Picking the men who possess such ability will always lessen top management chores.

17. Can he do his job without strain and yet show no sign of "loafing?" The higher the individual climbs the more essential it will be that he possess such ability.

18. Does he look for ways to do the job better? Where this has not been evidenced in the individual's regular work routines in the past, it should be given the closest study in considering his status insofar as any promotion is concerned. ##

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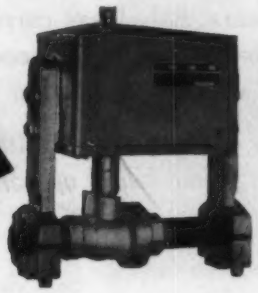

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Backed by technical service. All additives have been thoroughly tested, and data are available on their performance in engines, behavior in a wide range of gasolines, and effect on surface ignition, spark plug life and rumble. In addition, Ethyl's experienced automotive engineers are available to assist in handling technical problems.

Bright prospects for the future. For years, Ethyl has carried on many research programs looking for more and better phosphorus compounds. Many look interesting. One in particular holds much promise for the near future.

In one sentence, Ethyl offers you the finest line of phosphorus additives today (backed up by a full range of product services), and a prime source of more effective, lower-priced additives in the near future.

For full details, ask your Ethyl representative

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What's Happening...

Big Reorganization in U.S. for Mobil

New over-all organization plan will involve Magnolia Petroleum, General Petroleum and Mobil Producing

OPERATIONS OF the principal wholly-owned affiliates of Socony Mobil Oil Co., Inc., in the United States are being combined with the parent company's domestic operations into a single coast-to-coast operating unit, Mobil Oil Co. The transfer of operations will affect three affiliates: Magnolia Petroleum Co. in the Southwest, General Petroleum Corp. in the Far West, and Mobil Producing Co. in the North-Central and Rocky Mountain states. Operations of these affiliates will become the direct responsibility of Mobil Oil.

The changes are part of a new over-all organization plan, the first steps in which were taken by the Socony Mobil management more than two years ago. The plan went into effect for the company's top corporate structure and for its international operations on March 1 of this year.

No change in the ultimate ownership of any properties is involved. Magnolia and General Petroleum have been wholly owned by Socony Mobil for more than 30 years, and Mobil Producing was organized by Socony Mobil in 1954.

The management of Mobil's domestic business has been carried on by separate departments in Mobil Oil and in each of its domestic affiliates. The practical effects of this new plan will be to group in nationwide operating departments each of the principal functions of the business—exploration and producing, refining, transporting and marketing.

The transfer of operations of the three affiliates will start this Fall, and it is expected to take considerable time to complete.

Principal objectives of the organization plan are centralization of broad planning and policy-making, and decentralization of operating decisions through the placing of greater responsibility in the hands of individual managers.

Under the new plan, Magnolia and General Petroleum producing men and the Mobil producing operation will work through the Mobil Oil Co. Producing Department. The Magnolia refinery at Beaumont and the General Petroleum refineries at Torrance, Calif., and Ferndale, Wash., will become part of the Mobil Oil Manufacturing Department. Magnolia and General Petroleum marketing operations will be conducted through the Mobil Oil Marketing Department.

PETROLEUM REFINER Receives Safety Award

PETROLEUM REFINER has received a Public Interest Award for "exceptional service to safety" during the year 1958. These awards are made annually by the National Safety Council as a means of honoring public information media for interest and service "well above average" in the field of accident prevention. "It reflects leadership, initiative and originality," the National Safety Council stated. "And it means a continuous—not a sporadic—effort." The award was presented to the staff of PETROLEUM REFINER in the offices of Gulf Publishing Co., Houston. Shown at

the presentation ceremonies are (left to right) John J. McKetta, chairman of the editorial committee; Clayton A. Umbach, Jr., management and personnel editor; Jake Blackwell, regional vice president of the Texas Safety Council, and Harold L. Hoffman, process and construction editor.

A "Genuine" Commission For Father of Oil Industry

It has been 101 years since the unofficial title of "Colonel" was bestowed by a well meaning friend on Edwin L. Drake, father of the oil industry. Now a bill has been introduced in the Pennsylvania State Senate that would make the title official.

The bill, jointly sponsored by four state senators, would bestow upon Drake the posthumous rank of colonel in the Pennsylvania National Guard. The idea for the official title was first proposed by Genevieve Blatt, Pennsylvania secretary of internal affairs, in a speech at Titusville, Pa., last Spring.

The Pennsylvania bill would authorize the commonwealth's Military Affairs Department, with the governor's approval, to bestow the commission on Drake. Sponsors of the bill are state Senators Raymond P. Shafer, James S. Berger, Leroy E. Chapman and Joseph M. Barr.

New and Bigger Humble Oil Formed by Jersey Standard

A gigantic new Humble Oil & Refining Co. will be formed to carry out U.S. refining, producing and marketing operations of Standard Oil Co. (New Jersey) under plans revealed September 2. The Delaware-incorporated company will have Houston headquarters, following completion of the $95-million merger. Among the expected highlights in the deal are the following:

- Humble shareholders will be offered five shares of Jersey stock for four shares of Humble.
- Five major Jersey domestic affiliates will be absorbed by Humble.
- Jersey will be a holding company for Humble, its foreign operations and other domestic operations.
- Present key Humble executives will assume top posts in the new corporation.
- Humble's oval insignia would prevail throughout the entire nation, from border to border and coast to coast.

The Jersey-Humble agreement provides for nation-wide operation of domestic refining, producing, marketing and marine functions under unified management.

The merger plan will eventually include Esso Standard Oil Co., Carter Oil Co., Oklahoma Oil Co., and Pate Oil Co., all to be consolidated with Humble.

The consolidation came as only a mild surprise to most oil and business circles, as speculation of such a move had been triggered by Humble's plan to build a 44-story office building in Houston at a cost of $35 million.

U of H To Be Site Of 1959 ASTD Regional Workshop

The Southeast Chapter of the American Society of Training Directors will hold its annual regional workshop Oct. 9-10 at the Management Development Center of the University of Houston. Entitled, "Frontiers of Tomorrow" the workshop will present examples of the most effective programs and devices developed to date. There will also be new ideas and new concepts of those training personnel of business, industry and government who will attend.

The session which promises to be an attraction for many is the one on business games. In this session, participants will be divided into teams—each "managing" one of several different "companies." Team results will be calculated by an electronic computer, and the players will receive an analysis in the form of a financial report. Players will study the reports and make new sets of decisions, and this will continue for a specific number of "business years."

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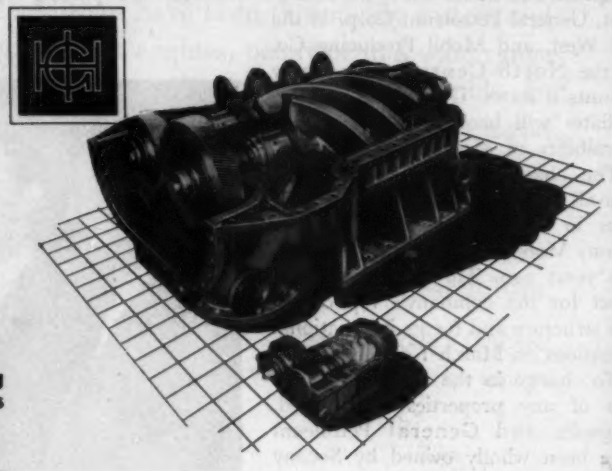

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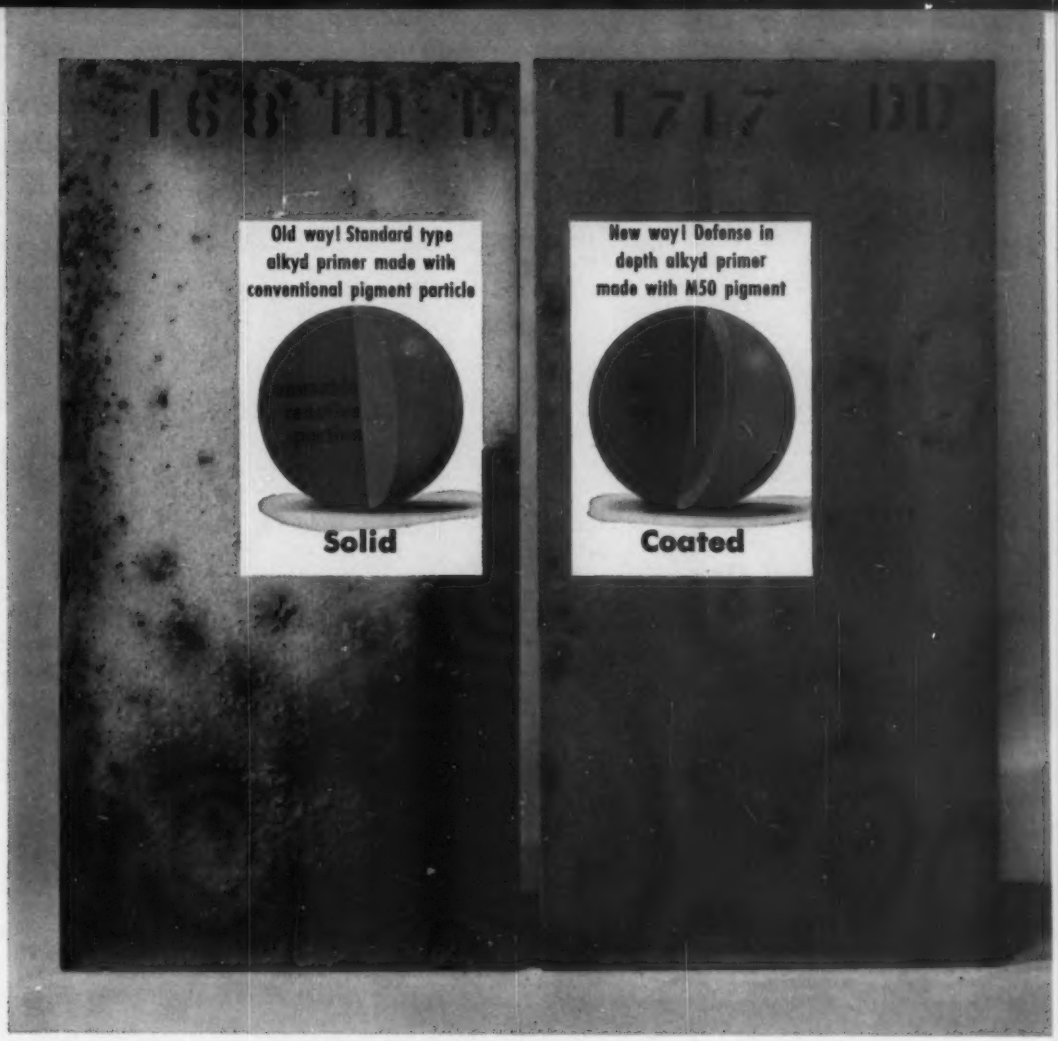
Old way! Standard type alkyd primer made with conventional pigment particle
Solid
New way! Defense in depth alkyd primer made with M50 pigment
Coated

Never before such durable tank protection

Proof tank paints with M50® pigment form rust-inhibitive films of outstanding strength and durability

Test panels like these *prove* what paints can do. And these two make it plain that paints containing *M50* basic lead silico chromate — a new National Lead rust-inhibitive pigment ... form outstandingly strong and durable protective films.

Excepting the pigment, both primers shown on the test panels contain the same ingredients. Both are applied (2.0 mils, dry) on rusted and mill-scaled steel (to increase test's severity). Both have been exposed 12 months in industrial atmosphere (Perth Amboy, N. J.) and 12 months in normal atmosphere (Sayville, L. I.) at 45° South. You can see the effect.

A striking difference! Yet film strengthening proves to be only one of many improvements that *M50* pigment makes in metal protective paints for steel tanks and structures. Now — with new *M50* pigment — your regular paint suppliers can provide metal protective paints with outstanding advantages:

- Weather-resistant anti-corrosive primers.
- Intermediate and finish paints *with* exceptional rust inhibition but *without* bilging hazard in sulfur-laden atmospheres.
- Finish paints in a wide range of decorative colors that don't fade or wash out.
- Alkyd-type conventional and heavy-coat paints with outstanding durability, package stability and sprayability.

What makes the difference? Basically the differences that make a difference in *M50* pigmented paints are inherent in the unique *M50* coated pigment particle itself (idealized particle shown above.) See, on the next page, the extra protections the *M50* particle provides in the dried film. See, too, how you can get the benefits of these new, much more durable, anti-corrosive paints.

M50 pigment is a product of National Lead Company

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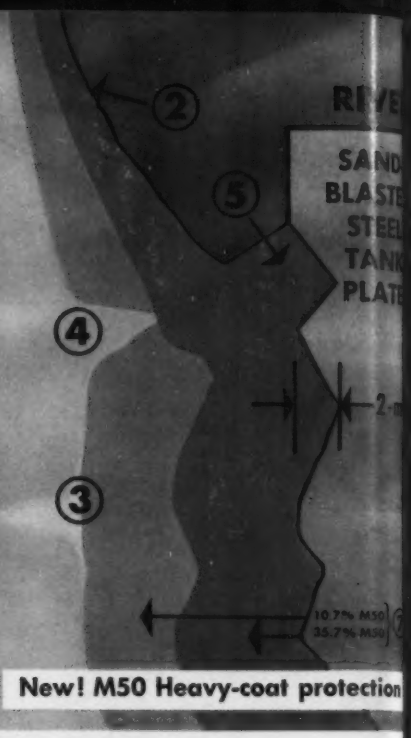
NEW! M50 3-coat protection.

1. **Pockets of rust prove less harmful on steel surfaces painted with conventional *M50* paints.** Vehicles penetrate and isolate existing rust. *M50* particles stop rusting action.
2. **Where paint film lies thin over tiny surface projections and sharp structural edges, the *rust-inhibitive* pigment content in all coats of *M50* paints provides extra protection.**
3. **Just-right flow characteristics of package-stable *M50* paints aid leveling on rough steel surfaces, promote smoothness, good appearance.**
4. **Inevitable "holidays" in film do not destroy protection. Again, *all M50* coats have both rust inhibition *and* weather resistance.**
5. ***M50* paints "wet" well, penetrate pits and crevices, carry *M50* protection to every part of these danger spots.**
6. **Lightweight *M50* particle aids formulation of new type heavy-coat paints with *uniform* rust inhibition throughout the film and low sag characteristics.**
7. **Every coat can have rust inhibition — not just the primer. Note percentages of *M50* in dry films. What's more, for equal weights of corrosion-inhibitive pigment, *M50* primers contain 40-60% more corrosion inhibition by volume than non-*M50* primers.**



New! M50 Heavy-coat protection

Sections through M50 Defense in Depth films show dramatic extra protection these new tank paints provide

Information on the preceding page proves that *M50* pigment paints form stronger protective films than anti-corrosive paints made with other rust-inhibiting pigments. The sections above show some of the ways in which these new paints perform better in the dry film. Below you will see *proof* that *M50* metal protective paints don't bilge, are unique for color stability and the color range in which they can be made.

Hold the *M50* pigment particle itself responsible for all these improvements . . . *Basic lead chromate* is known for exceptional rust-inhibiting action. In the *M50* particle, this reactive business portion of the partic is coated on an inert core . . . where *all of is available* to react. The coating is *fused* on shows superior resistance to chalking, er sion, chemical action. Unusual tintability due to the geometric configuration of t coated silica particle.

Why M50 Defense in Depth paints give anti-corrosion beyond all former concepts

Gray Alkyd Finish Coat
1 standard pigment alkyd primer coat
2 M-50 pigment alkyd primer coats
1 M-50 pigment alkyd primer coat

Exposed 9 years, 45°S. Each coat 1.5 mils

Proved corrosion and weather resistance

Exposed 4 years adjacent to refinery

Proved anti-bilging performance

Available in conventional and heavy-coat pa

Proved stability in wide range of colo

Are you concerned with tank or structure maintenance painting in your firm? If so, you are invited: (1) to visit National Lead's Sayville, L.I. test station, where you will see the results of the 20 years research that lies behind the *M50* pigment particle and the more than 10 years of exposure testing that lies behind *M50* pigment Defense in Depth paints; (2) to send coupon below for National Lead booklet, "Defense in Depth" a typical *M50* tank paint specifications.

Next time you purchase, specify *M50* pigme paints. Any paint manufacturer can supply y

M50 Defense in Depth

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Gentlemen: Please send me the "Defense in Depth" booklet together with typical tank paint formulas and color chips that I can use in specifying M50-type tank paints.

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Management Is Firm in Amoco Strike

As the strike at American Oil Co.'s Texas City refinery rolled into its third month, management took a firm hand in an effort to get workers back on their jobs. In letters to the 1,250 striking members of OCAW, Local 4-449, Amoco gave a deadline for reporting to work.

"If we do not hear from you, we will assume that you do not desire or intend to return to work, and you have decided to continue on strike. Commencing on August 28, we shall hire men to fill any jobs that remain vacant," the letters stated.

Following receipt of the letters a special back-to-work committee was formed by some of the strikers. However, at a special meeting called to poll strikers as to whether or not they should return to work, the effort was whistled and hooted to death before it could even be explained to 1,200 members present. There was no violence, but many people who wanted to hear both sides were escorted to the door.

Acting chairman of the meeting was Jimmy Brigance, an original member of the 25-man back-to-work committee which had been formed by W. E. Moss. Brigance attempted to open the meeting by explaining why it was called. He was immediately interrupted by A. F. Grospiron, secretary-treasurer of the local. Grospiron took over a floor microphone and spoke on "union policy." He said the committee had no right to call such a meeting to "decide whether or not they desire to cross the picket line." Then he personally led a walkout of most of the 1200 persons.

By the time that Moss and Brigance got to speak, there were only seven strikers left in the hall.

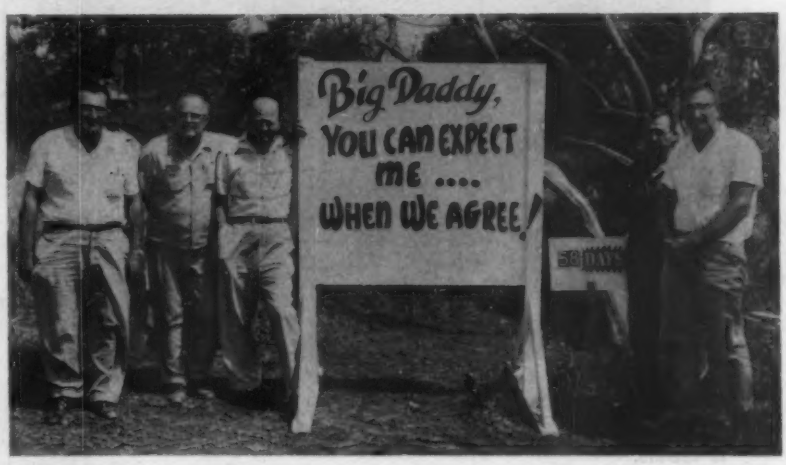
The next morning, the company reaffirmed its position to hire nonunion workers. Said B. F. Babin, plant superintendent, "We have the right to operate our business in the face of the strike, and we intend to do so in order to protect our business and to meet our obligations to our customers, our employes, and our stockholders."

An early count reveals that about 100 workers plan to take up the company's back-to-work offer.

Up until now, supervisory personnel have been running the plant to the tune of 100,000 bpd. However, there are some fears that as the company attempts to hire nonunion workers, the strike may get out of hand.

Across the street from the plant, grim strikers insist that the union "has no official plans" for action when the company starts hiring nonunion workers. Here is where the strikers gather to watch closely everyone who drives in and out of the gates, and to peer deep into the

Strikers pace silently back and forth as they picket Amoco's Texas City plant.



Across the street from the refinery, strikers gather to carefully observe all who enter and leave refinery.

Mirror on chair at left is used to reflect sun's rays into windows of plant administration building and to shine into lens of movie camera set up by company. Camera permanently records shift changes in case of any incidents.

plant with powerful binoculars. And although the union has no official plans, these men are convinced that no one will take their jobs.

Mexican Government Sets Up Petrochemical Entity

Mexico's President Mateos has signed a law setting up a new state entity to handle basic petrochemical production previously controlled by the government's Petroleos Mexicanos. The government proposal will give the Mexican government control of production of ethylene, acetylene, butadiene, propylene and 16 other basic petrochemicals.

Octane Ratings for August Up Slightly Over July

Gasoline on sale at service stations in August increased to national weighted averages of 99.2 octane number for premium and to 92.1 octane number for regular, according to the latest monthly survey of antiknock quality compiled by Ethyl Corp.

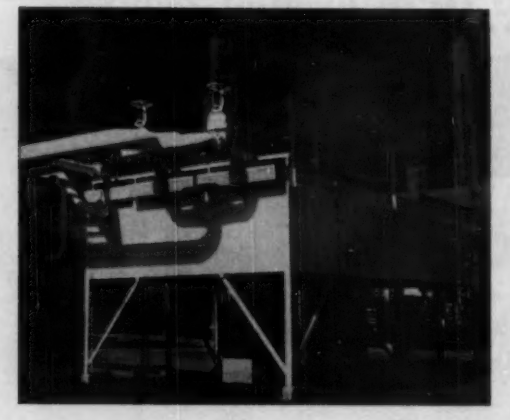
Both averages increased 0.1 octane number over July. Compared with a year ago, the premium average was 0.7 octane numer higher and the regular average was 0.9 octane number higher.

Thirty of the 57 cities in Ethyl's survey reported increases over July in the average octane number of their premium gasoline, two by 0.5 octane number or more. Sixteen cities reported decreases while 11 cities were unchanged. In regular gasoline, 28 cities reported increases over July in their average antiknock quality, three by 0.5 octane number or more. Seventeen cities reported decreases while 12 cities were unchanged.

Compared with the nationwide premium average of 9.2 octane number, 13 cities reported premium averages of 99.5 octane number or higher. In regular gasoline, 20 cities showed average octane ratings of 92.5 octane number or higher, compared with the national weighted average of 92.1 octane number.

For companies marketing more than one grade of gasoline, the survey showed a range of 100.9 to 103.0 octane number for the highest grade, on the basis of 47 samples in 25 cities.

Hi Fi SET?



Yes, SMITHCO Air Cooled Heat Exchangers DO have Hi Fidelity — they are engineered to provide faithful service long after others have ceased to operate.

A SMITHCO Heat Exchanger compares in other ways with a precision built Hi Fi set. For example, you wouldn't buy a Hi Fi in which all electrical connections were merely wrapped instead of one with conventional soldered connections, would you? Well, then, it follows that you wouldn't buy a heat exchanger with the fins wrapped instead of soldered to the tube.

SMITHCO is the ONLY major manufacturer of air cooled heat exchangers with solder bonded fin tubes. This solder bond assures the highest efficiency of heat transfer between fin and tube and has proven to be the most permanent bond yet devised.

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AIChE Sponsors Computer Program Interchange

AIChE is sponsoring the interchange of computer programs of the type that are useful to engineers in the petroleum and chemical industries.

Most engineers now have access to a digital computer. Whether the engineer rents machine time or uses his company's computer, the potential value of this tool to him is almost entirely a function of the number and type of programs available for his use. Through its Machine Computation Committee, AIChE is encouraging every computer user to offer for publication the details of all programs which could be of use to engineers in the petroleum and chemical industries. Through such an interchange of working programs (1) these industries will realize the greatest advantage from the large number of computer programs that have been written without wasteful duplication of effort and (2) every engineer would be provided tools by which he can increase his productivity and hence his value to his employer.

AIChE is interested in publishing manuals describing computer programs which have a general purpose nature in the following fields:

1. Chemical engineering calculations for design or analysis
2. Applied mathematics
3. Statistical analysis of experimental and operating data
4. Computer control of processes
5. Analog techniques in dynamic analyses
6. Data processing for data reduction or management controls
7. Engineering calculations for design of chemical or petroleum facilities (Civil, Electrical, Mechanical, etc.)
8. Reservoir engineering

Companies which have already offered to prepare program manuals for publication include Esso Research and Engineering, Humble Oil and Refining, Phillips Petroleum, Socony Mobil Oil, Standard Oil of California, Arthur G. McKee, E. I. du Pont de Nemours, Monsanto Chemical, Dow Chemical, and International Business Machines.

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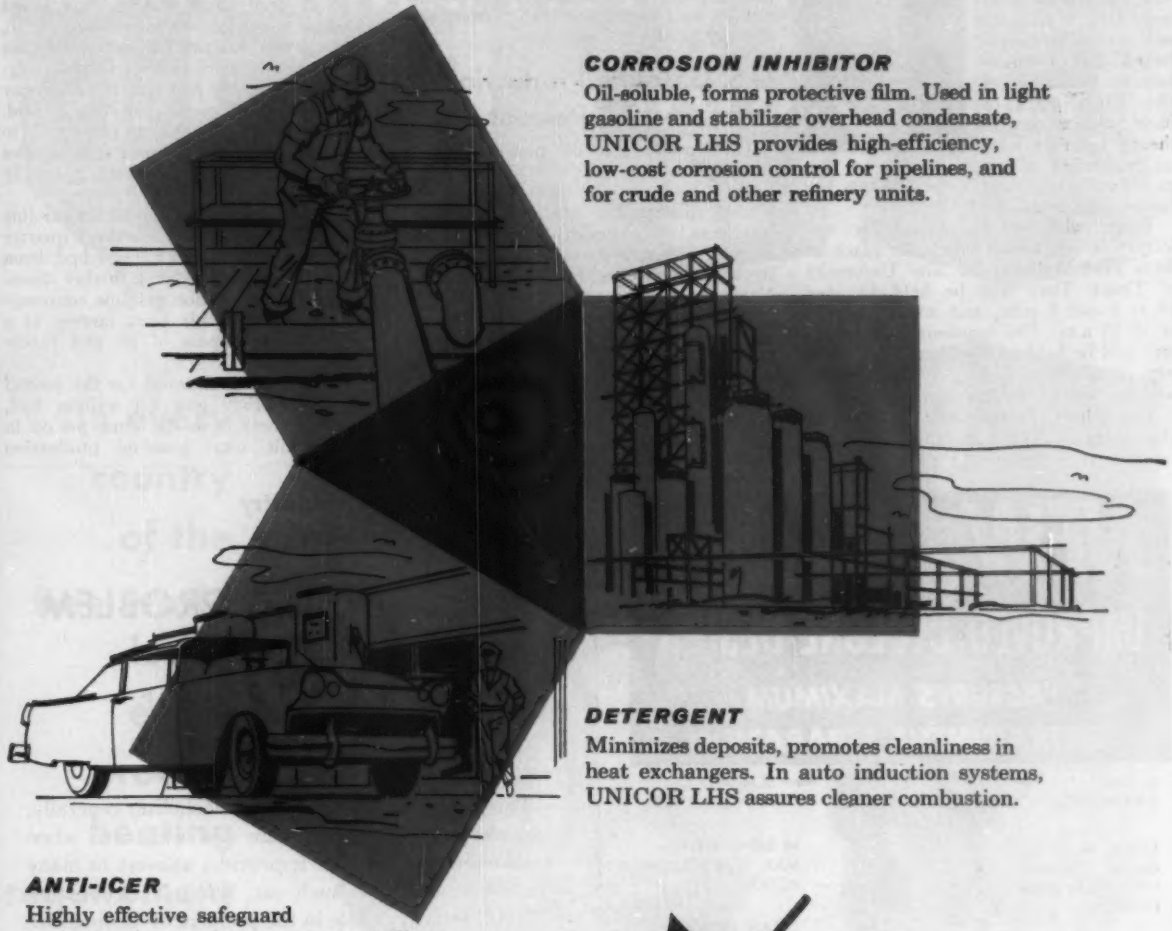

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gram may obtain further information from the Machine Computation Committee, c/o AIChE, 25 West 45th St., New York 36.

E. P. Schoch Lectures Slated For October 16 and 17

Dr. Theodore J. Williams, of Monsanto Chemical Co., St. Louis, Mo., will be the fourth lecturer for the E. P. Schoch Series, held yearly at The University of Texas. His subject will be process control. Dr. Williams will give a relatively brief but comprehensive discussion of the highlights of basic process control theory together with an evaluation of the present status and future trend in this field.

Williams

There will be no charge for this lecture series, which will take place at Batts Hall Auditorium, The University of Texas. They will be held October 16 at 2 and 8 p.m., and on October 17 at 10:15 a.m. The luncheon (no speakers) will be held on October 17 at 12:30 p.m., at a cost of $2-$3 per plate. Ladies will be invited to the luncheon.

The Schoch Lecture is not limited to University of Texas alumni.

National Oil Company For Venezuela Is On the Way

Venezuela plans to establish a national oil company within a few weeks, according to the nation's President Betancourt, who emphasized that the company would not be "the expression of a conflict between the Venezuelan government and foreign companies with investments in Venezuela." In explaining the move, President Betancourt said, "Our relations with the companies are normal, and are no different from the normal relations in the period from 1945-48 when I headed a democratic government . . . It is simply that Venezuela, the world's biggest petroleum exporter, cannot continue without its own instrument for participating directly in the oil industry."

U.S. Gasoline Production Increases 2.8 Percent

U.S. production of gasoline in the third quarter of 1959 will run about 4.1 million bpd, up 2.8 percent from the second quarter but about 220,000 bpd less than the forecast demand as the refining industry starts reducing surplus stocks, estimates E. I. du Pont de Nemours & Co.

Breaking down its third-quarter forecast, the company's Petroleum Chemicals Division said domestic demand for motor gasoline should be 4 million bpd, with domestic aviation requirements adding 210,000 barrels to the daily rate. Third quarter export demands on U. S. production should total 25,000 barrels of motor gasoline and 40,000 barrels of aviation gasoline per day.

Compared with the third quarter of 1958, domestic demand for motor gasoline is the only segment of the market expected to show an increase. The forecast gain in that area is 4.4 percent, based on normal seasonal expectations and a continuation of good economic conditions. Domestic demand for aviation gasoline in the third quarter is forecast to decrease by 19.2 percent or 50,000 bpd from the same period last year, when military requirements were especially heavy.

In its review of the second quarter of 1959, the company noted that domestic demand for motor gasoline continued to show good improvement over 1958, although the 4.3 percent estimated gain is far below the 7.0 percent increase registered during the first quarter. Highway consumption of motor gasoline, it said, appears to be responding very well to the strong increase in motor vehicle sales over 1958 and the nation's generally healthy economy.

Domestic demand for aviation gasoline was 210,000 bpd in the second quarter of this year, down only 2,000 bpd from the same period in 1958. A further downward trend in aviation gasoline consumption is expected this year, largely as a result of the impact of jet and turboprop planes.

Total gasoline demand for the second quarter of 1959 was 4.3 million bpd, up 3.8 percent from the same period in 1958, while total gasoline production

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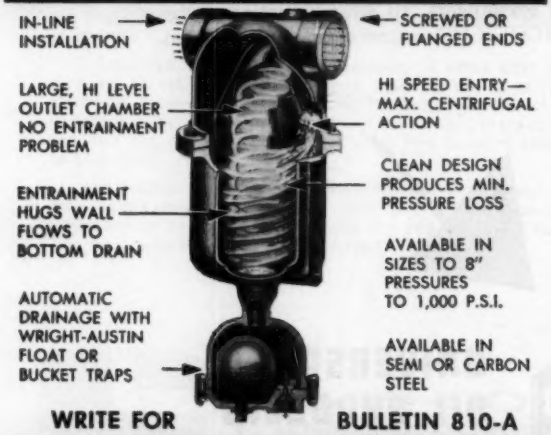
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This book deals not only with alcoholism generally, but also with its effects, care and treatment when encountered on the job. It provides answers to many important questions such as: What is alcoholism? What is industry's role in the problem of alcoholism? What are the community problems related to alcoholism? What are the major signs that indicate existence of a drinking problem? What is the treatment? Is there a cure?

The author is assistant medical director of E. I. Du Pont de Nemours and Co., Inc. Du Pont is well known for its efforts to rehabilitate the alcoholic worker.

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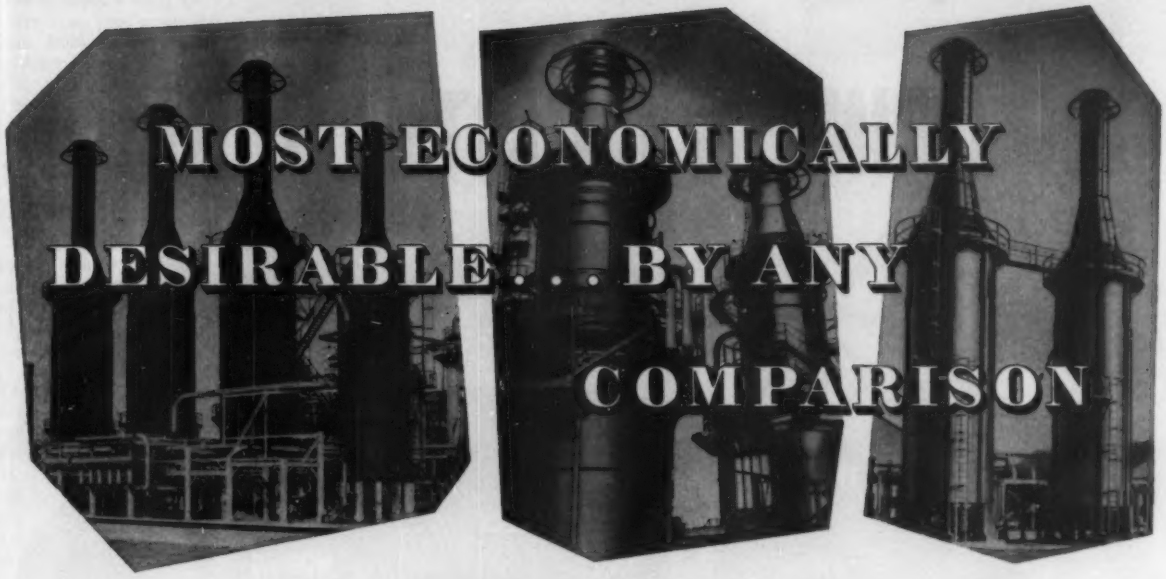

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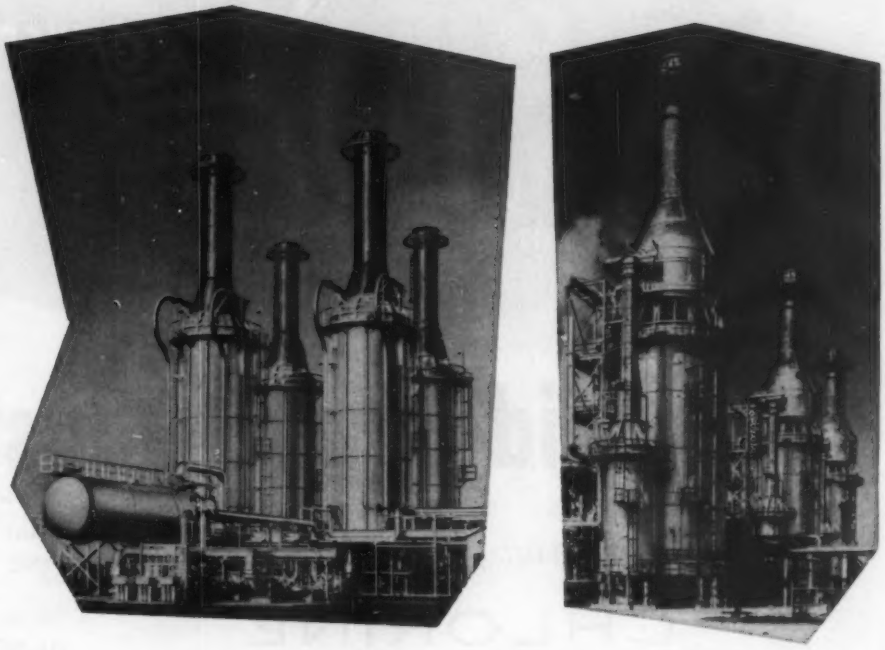

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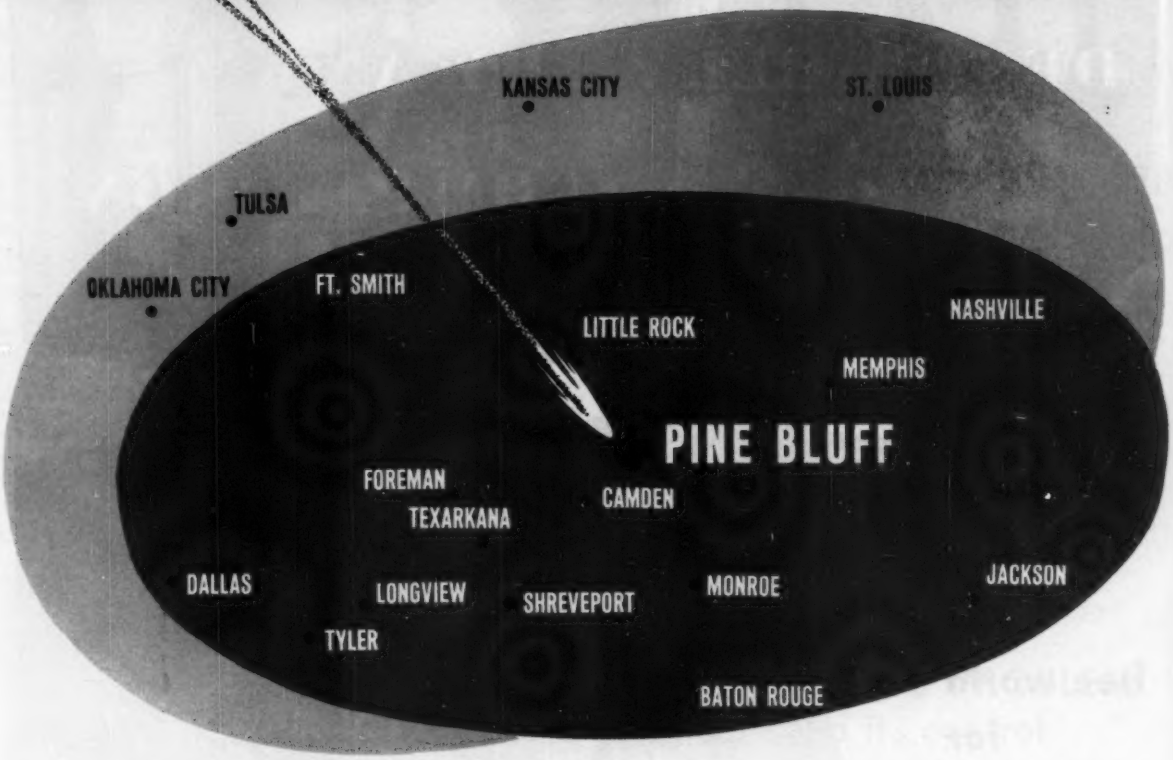

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was 4 million bpd, or 7.9 percent more than last year's second quarter. Gasoline stocks at the end of the second quarter of this year were estimated at 198 million barrels, as compared with 186 million barrels at the same time in 1958.

Domestic Crude Oil Demand Estimated for September

Consumption and export of U.S. domestic crude oil in September has been estimated at 6.8 million bpd by Bureau of Mines. The forecast includes estimates of total gasoline demand amounting to 4.2 million bpd in September, a gasoline yield of 45 percent, and crude runs of 7.65 million bpd. The Bureau also estimates that refinery runs will decline.

Gasoline stocks at the end of July were about 5.8 million barrels higher than in 1958, and stocks of distillate fuel oil were up 19.8 million barrels. Residual stocks were 10.8 million barrels lower than in 1958, with more than half of this reduction in the West Coast District.

Oil Imports Administration Evaluates Trade Pacts

About $75 million per year is probably being gained by inland refiners by trading their Districts 1-4 imports to East Coast refiners for domestic crude, according to the Oil Imports Administration. It is estimated that about 257,000 bpd of imports brought Districts 1-4 are exchanged for domestic crude.

The OIA said that no estimate was made for District 5 because there is relatively little trading of imports allocations going on in the West Coast area in the current allocation period.

Englehard to License Atlantic Refining Process

Englehard Industries has taken over licensing of Atlantic Oil Co.'s Catforming process, and will supply the catalyst used in it. A resulting new company to be headquartered in Hanover, Germany, will supply the two catalysts to refineries in Europe and elsewhere abroad. Kalie-Chemie, A.G., Hanover, which has supplied the catalyst in the past, is expected to take part in the new company.

OCAW Named to Represent Humble Group at Baytown

The OCAW union has been elected to represent the more than 3,000 production and maintenance employes at Humble Oil & Refining Co.'s Baytown, Texas, refinery. Humble employes, who had been represented for 23 years by Baytown Employes Federation, an independent union, voted 1,621 for OCAW and 1,196 for BEF. Clerical workers and employes at the company's Houston ship channel terminal will continue to be represented by BEF.

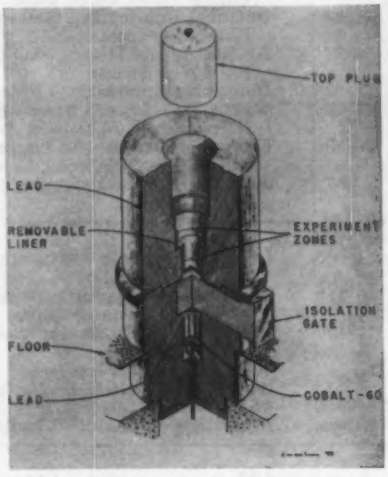
June LPG Production Up One Percent Above May

Daily average production of natural gas liquids in June was 36 million gallons, one percent above May, 1959, according to the Bureau of Mines. Daily average production of liquefied gases at refineries was 8 million gallons, the same as last May. Demand for LPG for chemical and fuel uses went up 13 percent from May.

LPG stocks totaled 1.03 million gallons or 377 million gallons higher than a year ago. Underground stocks of LPG totaled 813 million gallons in June, an increase of 133 million gallons, while daily average demand for natural gasoline decreased two percent in June.

New Lube Oil Is Developed For Free-Piston Engines

A new lube oil has been developed by Esso Research and Engineering Co. The company claims that the oil will extend the period between servicings of free-piston engines. The product was tested on a series of trans-Atlantic runs in a converted Liberty ship, the G.T.S. "William Patterson." The new lube which is being further developed both in the United States and abroad, was developed by Esso Standard S.A.F., Port Jerome, France.



Cobalt Irradiation Unit Installed at Shell Lab

A cobalt-60 irradiation unit, a research tool used in radiation process studies, has been installed at Shell Chemical Corp.'s Synthetic Rubber Division research laboratory, Torrance, Calif. Radiation derived from the cobalt-60 source will be utilized in the study of improved rubber and plastics products and the development of radiation-resistant products for use in atomic power plants.

The new facility will supplement an existing three million volt Van de Graaf accelerator already used by Shell Chemical's affiliate, Shell Development Co.,

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Happenings . . .

Emeryville, Calif., in research activities for all Shell companies.

The cobalt source consists of 20,000 curies of radioactive cobalt which emits the gamma radiation necessary for experimental work. A curie is a measurement of the number of radioactive atoms disintegrating in one second in a given amount of radioisotope.

The cobalt-60 in the shipment weighs about two pounds and is enclosed in 13 tons of steel-covered lead shielding—a portable package unit designed and constructed in Philadelphia by Nuclear Systems, a division of the Budd Co.

The unit was installed in a specially constructed "exclusion room" adjacent to the recently completed radiation laboratory at the Torrance plant. Safety features include special instruments, mechanical interlocks and alarms to assure safe operation.

- Changing Times -

Arabian American Oil Co. plans to ship fully refrigerated LPG by ordinary tankers equipped with refrigeration machinery to receive the product at —25°F. The product will be shipped **from Aramco's Ras Tanura refinery.**

Australia has refused offer of Soviet crude oil in spite of prices 10 to 15 percent below Persian Gulf competition. Deal would have involved oil-for-wool swap.

Senate Interior Committee has approved **move to establish joint Senate-House committee to determine national fuels policy.** Coal industry is said to be heavily backing measure.

House has passed bill extending Air Pollution Control Act two more years, while Senate-passed bill would extend act four years. Latter measure would boost yearly federal outlays from $5 million to $7.5 million.

Ultramar of London plans purchase of Panama Refining and Petrochemical Corp., a Panamanian firm which owns Golden Eagle Refining Co., Los Angeles.

Filipino investors, headed by F.G.U. and Insular life insurance companies, **have purchased 25-percent interest in Shell Oil and Shell Refining companies,** Philippines. Deal involves $6.5 million.

Industrial College of the Armed Forces is offering **correspondence course, "The Economics of National Security." Course, which is free, involves 22 bound volumes and five units of study.** For full information write to Commandant, Industrial College of the Armed Forces, Washington 25, D.C. Attn., Correspondence Branch.

AIChE has changed name of its junior award to Allen Philip Colburn Award in honor of the late University of Delaware provost.

Yuba Consolidated Industries, Inc., has acquired Petro-Chem Development Co., and its American and Canadian subsidiaries. Petro-Chem will keep present name and serve as Yuba subsidiary.

Tidewater Oil Co. has filed report with Department of Justice **regarding its proposed merger with Skelly Oil Co.** Report contains answers to 16 questions on merger, submitted by Department of Justice.

Meetings Calendar

Sept.	
20–23	**American Society of Mechanical Engineers,** Petroleum Mechanical Engineering Conference, Rice Hotel, Houston.
21–23	**Workshop on Use of Passive Element Analog Computers in Oil Work Refinery Research,** Columbia University, New York.
21–25	**Instrument Society of America,** Annual Instrumentation-Automation Conference and Exhibit, International Amphitheater, Chicago.
22–24	**Industrial Nuclear Technology Conference,** Morrison Hotel, Chicago.
23–24	**Western Petroleum Refiners Association,** Rocky Mountain Technical-Industrial Relations Meeting, Henning Hotel, Casper.
24–25	**American Society for Quality Control,** Annual Technical Conference, Shamrock-Hilton Hotel, Houston.
27–30	**American Institute of Chemical Engineers,** Meeting, Hotel St. Paul St. Paul.
28–30	**American Oil Chemists Society Meeting,** Hotel Statler, Los Angeles.
29–30	**WPRA,** Management Seminar, Western Hills Hotel, Wagoner, Okla.
28-Oct 1	**American Welding Society,** Fall Meeting, Sheraton-Cadillac Hotel, Detroit.
29-Oct 1	**National Association of Corrosion Engineers,** Western Region Conference, Bakersfield Inn, Bakersfield, Calif.
30-Oct 1	**Institute of Radio Engineers and AIEE,** Industrial Electronics Symposium, Mellon Institute, Pittsburgh.
Oct.	
1– 2	**NACE,** Southeast Region Conference, Jacksonville, Fla.
5– 8	**NACE,** Northeast Region Conference, Lord Baltimore Hotel, Baltimore.
7– 8	**WPRA,** Annual Stream Pollution and Waste Disposal Conference, Broadview Hotel, Wichita.
8– 9	**California Natural Gasoline Association,** Fall Meeting, Huntington-Sheraton Hotel, Pasadena, Calif.
11–16	**American Society for Testing Materials,** Pacific Area National Meeting, Sheraton-Palace Hotel, San Francisco.
12–14	**National Electronics Conference,** Hotel Sherman, Chicago.
12–15	**NACE,** South Central Regional Meeting, Denver.
20–22	**American Standards Association,** National Conference on Standards, Sheraton-Cadillac Hotel, Detroit.
20–22	**ASME-ASLE,** Lubrication Conference, Sheraton-McAlphin, New York.
20–22	**NACE,** North Central Region Conference, Cleveland.
23	**Natural Gasoline Association of America,** Southern Regional Meeting, Carlton Hotel, Tyler, Texas.
26–28	**National Lubricating Grease Institute,** Annual Meeting, Roosevelt Hotel, New Orleans.
27	**AIChE,** Annual Meeting and Engineering Symposium, New York Section, Hotel New Yorker.
28–29	**Computer Applications Symposium,** Morrison Hotel, Chicago.
28–29	**WPRA,** Question and Answer Session on Refining Technology, Rufus Garrett Hotel, El Dorado, Ark.
28–30	**Society of Automotive Engineers,** National Fuels and Lubricants Meeting, La Salle Hotel, Chicago.
30	**AIChE,** South Texas Section Technical Meeting, Moody Center, Galveston, Texas.
Nov.	
4– 6	**Institute of Radio Engineers,** National Automatic Control Conference, Sheraton Hotel, Dallas.
9–11	**American Petroleum Institute,** Annual Meeting, Conrad Hilton, Palmer House, and Congress Hotels, Chicago.
11–13	**National Fire Protection Association,** Fall Conference, Hotel Fort Des Moines, Des Moines.
17–18	**WPRA,** Computer Conference.
20	**NGAA,** Panhandle-Plains Regional Meeting, Herring Hotel, Amarillo.
29-Dec4	**ASME,** Annual Meeting, Chalfonte Haddon Hall, Atlantic City.
30-Dec4	**Exposition of Chemical Industries,** New York Coliseum.
Dec.	
3– 5	**ACS,** Southwest Regional Meeting, Baton Rouge.
6– 9	**AIChE,** West Coast Meeting, Sheraton Palace Hotel, San Francisco.
Jan. 1960	
22	**NGAA,** Gulf Coast Regional Meeting, Robert Driscoll Hotel, Corpus Christi.
Feb.	
1–5	**ASTM,** Committee Week, Hotel Sherman, Chicago.
23–26	**ASME,** Symposium on Thermal Properties of Gases, Liquids and Solids, Purdue University.
26	**NGAA,** Permian Basin Regional Meeting, Lincoln Hotel, Odessa, Texas.
March	
14–18	**NACE,** Annual Meeting, Memorial Auditorium, Dallas
18	**NGAA,** Oklahoma Regional Meeting, Biltmore Hotel, Oklahoma City.
April	
19–21	**Southwestern Gas Measurement Short Course,** Drill Hall, North Campus, University of Oklahoma.
20–22	**National Petroleum Association,** Semiannual Meeting, Hotel Cleveland, Cleveland.

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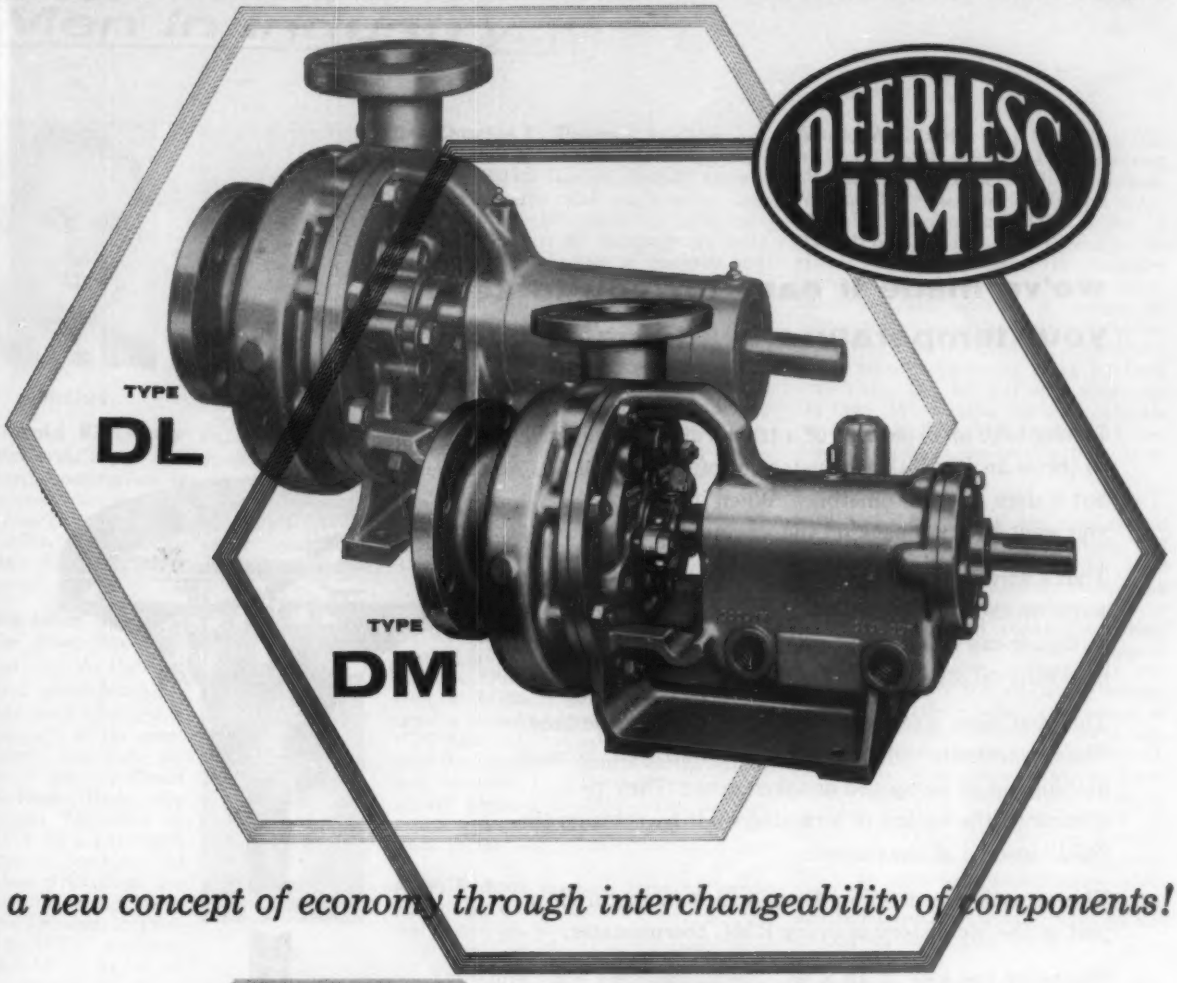

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Harold F. Cleary and **Donald N. McCord,** Stone & Webster Engineering Corp. construction engineers, have been elected vice presidents of the company. Others elected vice presidents are **M. H. Cutler,** engineering manager, and **William R. Prang,** West Coast district manager.

Herschel Y. Hyde, Tidewater Oil Co. group vice president for manufacturing, marketing and petrochemicals, has been elected a member of the company's board to replace the late **David S. Hecht.** Hyde, who joined Tidewater in 1928 as a research chemist, was elected vice president for manufacturing, Western Division, in 1946. In 1954, he was named to head all Tidewater refining operations, and was recently named to the group vice president post.

Hyde

J. L. Olvey has been elected assistant vice president of The Frontier Refining Co., Denver. With Frontier since 1939, he has served in many capacities, and in 1957 was made assistant refinery manager. **Donald E. Arnell,** formerly assistant to **H. E. Armitage,** executive vice president of Frontier, was elected assistant vice president, administration. **Roy H. Jordan** was elected assistant treasurer.

Peter H. Vossos has joined the staff of Whiting Research Laboratories, Standard Oil Co. (Indiana) to carry out research on petroleum asphalt. He has a B.S. degree in chemistry from South Dakota School of Mines and Technology and a M.S. degree from Iowa State College.

John Paul Jones, has been named an associate director of public relations, The Standard Oil Co. (Ohio). Following work in the Operations and Industrial Relations Departments of Youngstown Sheet & Tube Co., and on the industrial relations staff of United States Steel Corp.'s Youngstown works, he joined Sohio in 1945, as chief of employe relations, Manufacturing Department.

Dr. Charles L. Thomas has been appointed Sun Oil Co.'s first scientific advisor. He will furnish scientific leadership in research and engineering and pursue his research specialties independently. **Dr. Robert M. Kennedy** succeeds Dr. Thomas as director of research and development. Dr. Thomas joined Sun in 1951 as a staff assistant in research and development. He then became manager of the chemical research laboratory, and was named director of the division in 1956. Dr. Kennedy came to the company as a research chemist in 1941, and was named manager of the basic research in 1953. He was appointed associate director of research and development in 1956.

William A. Dunlap has been advanced to manager of The Dow Chemical Co.'s Plastics Technical Service activities in the South. Dunlap, who has been a staff member at PTS facilities at the Dow Texas Division, Freeport, succeeds **Robert W. VanSickle,** recently named manager of a new polyethylene film plant, Findlay, Ohio. Dunlap joined Dow in 1951 at Midland headquarters. He became a technical service engineer in the PTS heat fabrication section in 1953, field development engineer in the extrusion section in 1954 and customer service engineer in 1956, when he was transferred to the Texas group for PTS work in the South.

A. P. Endres has been appointed manager of public relations services for General Petroleum Corp. With the company 20 years, Endres started as a division sales clerk in the Marketing Department. In 1946, when the Public Relations Department was formed, he became assistant to the manager, a position he held until his present promotion. Endres attended Stanford University and is a member of the Petroleum Club of Los Angeles, the Los Angeles Athletic Club and the public relations committee of Occidental College.

Endres

Kenneth M. Brown, Universal Oil Products Co. technical service engineer, has been named by Committee D-16 of the ASTM to head a subcommittee establishing international specifications for aromatic hydrocarbons. The ASTM subcommittee will work through ASA with the International Standards Organization to set up purity specifications and testing methods for benzene, toluene, xylene and other aromatics derived from coal tar and petroleum. Brown has been the company's representative to ASTM's committee concerned with aromatic hydrocarbons since 1950.

Frank W. Kroll, Jr., has joined the staff of Esso Research & Engineering Co., along with **Thomas H. Sonnichsen, Jr.,** and **Dr. Theodore J. Stenuf.** Kroll was with Esso Standard Oil Co. for 20 years before joining Esso Research. He received his B.S. degree in chemistry from Polytechnic Institute of Brooklyn. Sonnichsen was with E. I. duPont de Nemours & Co., Wilmington, Del., for eight years. He received his B.S. degree in electrical engineering from Bucknell University. Dr. Stenuf was also with Du Pont, Wilmington, for six years. He received his B.S., M.S. and Ph.D. degrees in chemical engineering from Syracuse University.

Raymond M. Camp has been named superintendent of crude, cracking and coking operations at Tidewater Oil Co.'s Delaware refinery. Eugene Andrechak was appointed superintendent of economic planning and accounting. Camp joined Tidewater in 1938 as a chemist at the Avon, Calif., refinery. He was superintendent of the alkylation-isomerization plant there when transferred to Delaware as superintendent of alkylation, polymerization, reforming and desulfurization, his most recent post, in June, 1956. Andrechak joined the company in June, 1951, as a process control engineer at Tidewater's former Bayonne refinery. Assigned to the plant in August, 1956, as supervisor of economic planning, he took his most recent post, acting superintendent of economic planning and accounting in August, 1958.

F. Lawrence Doherty, assistant personnel manager of Stone & Webster Engineering Corp. since 1951, has been promoted to personnel manager. A licensed attorney, he attended Suffolk University Law School, and was admitted to the Massachusetts Bar in 1941 and the Federal Bar in 1943.

Charles Leet, a petroleum refining engineer for 28 years, has been elected a director of Standard-Vacuum Oil Co. effective October 1. He joined Esso Standard Oil Co. as a student engineer, Bayway refinery, New Jersey, in 1930 following graduation from West Virginia University where he received a chemical engineering degree. He went to Esso's Baton Rouge refinery in 1931, moving through a series of process engineering, development and research assignments to assistant general manager in 1950. Appointed manager of the company's Bayonne, N. J., refinery in 1953, Leet was then selected to head Esso's East Coast Manufacturing Division. He joined

Leet

Men . . .

Creole Petroleum Corp. and became a director in 1956 and has been a contact director for petroleum economics and refining at that company's Caracas, Venezuela, headquarters.

Fleck

Snyder

Dr. Lloyd Snyder has been named senior research chemist at Union Oil Co. of Calif.'s Research Center, Brea, Calif. **Ray N. Fleck** has been promoted to research associate.

Benjamin A. Bolton has been named a project chemican engineer at Whiting Research Laboratories, Standard Oil Co. (Indiana). Since he joined Standard in 1954, he has carried out studies of applications for new petrochemical products. Bolton has a B.S. degree in chemical engineering from Lafayette College, and his M.B.A. degree from Northwestern University, and is a member of ACS.

Ray Harrison has been named by Tideland Oil Co., to assist the manufacturing manager in petrochemical development. **Lloyd C. Forbes** was appointed superintendent of utilities, oil dispatching and sulfur recovery; **Charles H. Bennett** was named staff assistant to the manager, and **Erich R. Westfield** was appointed supervisor of economic planning. Harrison had been superintendent of utilities, oil dispatching and sulfur recovery. Forbes was previously supervisor of crude, coking and cracking, while Bennett was technical foreman of the fluid coker.

Westfield joined Tidewater last year as an analyst and shortly afterward was named acting supervisor of economic planning.

Ivan J. Sitar has been named a project engineer at the Seymour, Ind., laboratories of the Research and Development Department, Standard Oil Co. (Indiana). He joined Standard in 1950, and until 1955 worked on improving refining methods. Sitar has B.S. and M.S. degrees in chemical engineering from Northwestern University. He is a member of AIChE, the American Rocket Society and Sigma Xi.

Wilson C. Rich, Jr., has been named chief process engineer in charge of the Process Division, J. G. White Engineering Corp. An independent consulting engineer for five years, he was formerly in process design and economic evaluation for Esso Research and Engineering Co.

Winthrop M. Barnes has been appointed assistant director, petrochemicals, of Sun Oil Co.'s Research and Development Division. Before joining Sun, he was research manager of the Industrial Economics Department, Southwest Research Institute, San Antonio, Texas. Barnes previously was director of market research, Chemical Division, Celanese Corp. of America.

R. A. Pratt, manager of personnel and industrial relations for Shell Pipe Line Corp., has been named administrative superintendent of Shell Oil Co.'s Norco refinery. **R. H. Hord,** manager of personnel and industrial relations at Wood River, Ill., will succeed Pratt at Shell Pipe Line, while **A. J. Martin** will succeed Hord at Wood River. Martin is now a representative in Shell's head office industrial relations department.

Joseph H. Sperry, former Gulf Oil Corp. staff lawyer at Houston, has been transferred to the company's general offices in Pittsburgh as a coordinator of labor relations, Organization Planning and Employe Relations Department. With Gulf 16 years, Sperry has B.A. and LL.B. degrees from The University of Texas.

J. R. Barsalou has been named operations manager at Humble Oil & Refining Co.'s Baytown, Texas, refinery. He is responsible for the Process, Operating Services, and Maintenance and Construction Divisions. Barsalow had been general foreman of light oil treating and

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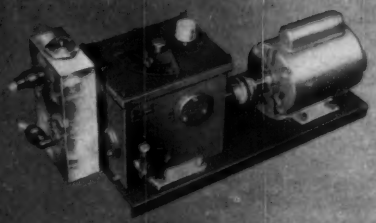

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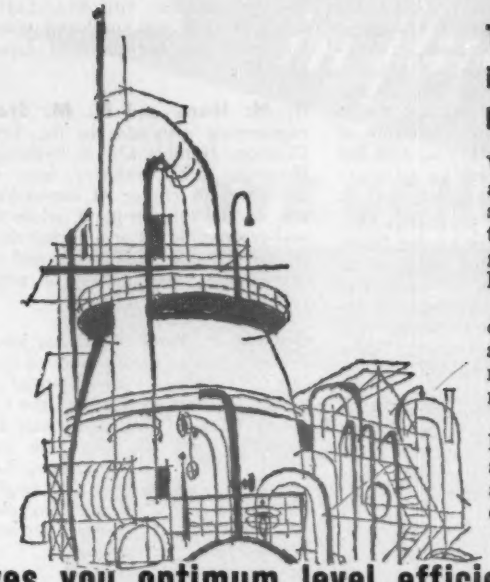

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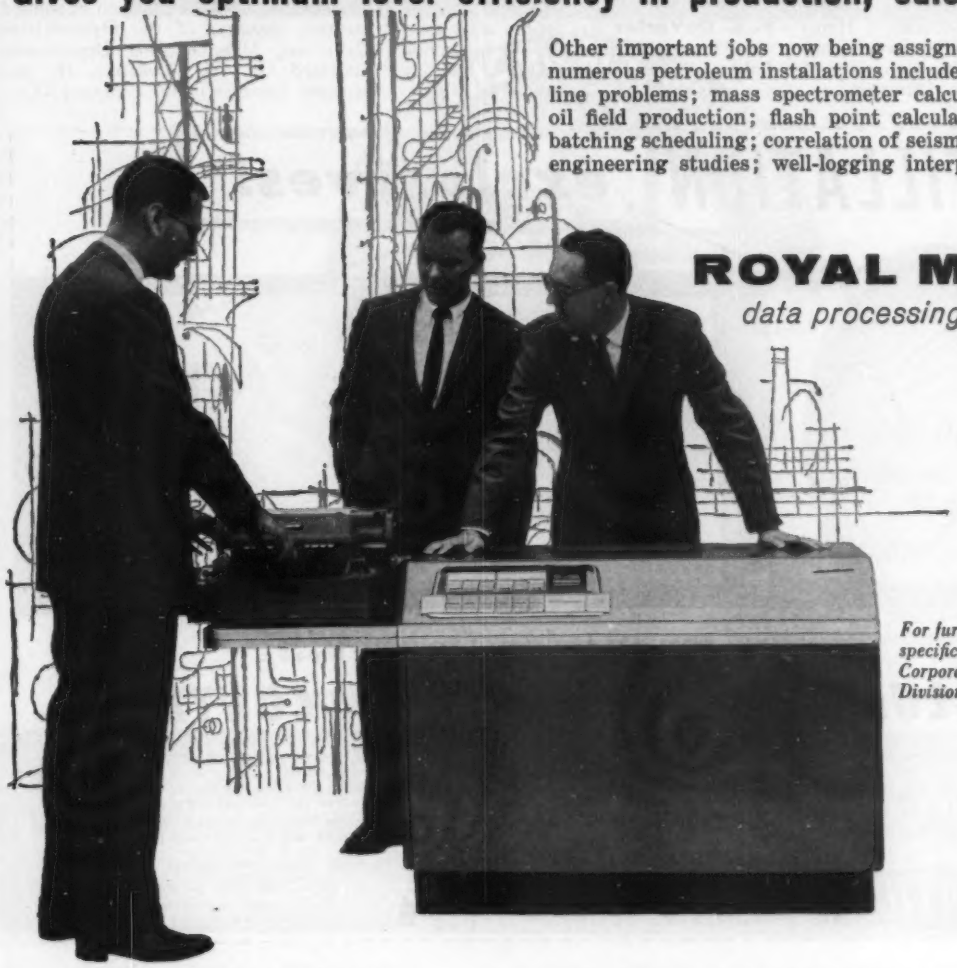

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Men . . .

assistant head of the Coordination Division, Baytown Refinery. He also served a year as technical assistant to the manager of manufacturing in the Houston office. He has a B.S. degree in chemical engineering from the University of Oklahoma.

J. E. Lawson has been promoted to supervising engineer, Technical Division, Humble Oil & Refining Co.'s Baytown Texas, refinery. To be in charge of the distillation section, Lawson holds a B.S. degree in chemical engineering from The University of Texas. **E. H. Oliver** and **J. H. McCulley** have been named general foremen, Process Division. **W. K. Roquemore** and **J. R. Lander** have been named assistant general foremen, Process Division, Cracking & Polymerization Department. All four men are graduate chemical engineers.

W. H. Creel has been named manager of Phillips Petroleum Co.'s Refining Department, Bartlesville. He joined Phillips in Bartlesville in 1924 after graduation from the University of Oklahoma. Creel held several supervisory positions in the Refining Department and has been its assistant manager since 1951.

J. C. Gorman has been named foreman of the Inspection Laboratory, Humble Oil & Refining Co.'s Baytown, Texas, refinery. He attended the University of Michigan and Columbia University.

Dr. Norman G. Gaylord has been elected vice president, research and development, Polymer Division, Western Petrochemical Corp. He was formerly assistant director of the Organic Chemistry Department, Interchemical Corp. Dr. Gaylord is senior lecturer at the Polytechnic Institute of Brooklyn, and has served as adjunct professor of chemistry, Canisius College, Buffalo, N.Y. Prior to joining Interchemical, he was with E. I. du Pont de Nemours & Co. Holder of M.S. and Ph.D. degrees from the Polytechnic Institute of Brooklyn, he is a member and past chairman of the Lecture Series Committee, New York Section, ACS.

Gaylord

Thomas M. Dailey, Jr., executive assistant to the president of Tidewater Oil Co., has been appointed manager, Planning and Personnel Department, Los Angeles headquarters. Holder of a B.B.A. degree from the University of Texas, he joined Tidewater in 1955. He was previously with Humble Oil and Refining Co. and Woodley Petroleum Co.

P. L. DeVerter has retired after serving 33 years as head of the Inspection Laboratory at Humble Oil & Refining Co.'s Baytown, Texas, refinery.

David B. Barlow has been named comptroller of California Chemical Co. For four years he had been secretary-treasurer of two other Standard subsidiaries, Salt Lake Pipe Line Co. and Salt Lake Refining Co., Salt Lake City, Utah. Barlow has been with Standard since 1947, when he was employed as accounting supervisor for the Salt Lake Pipe Line Co.

D. M. Haas and **H. M. Stewart,** engineering associates in the Technical Division, Humble Oil & Refining Co.'s Baytown, Texas, refinery, have retired. Haas was in charge of engineering design on the toluene plant, while Stewart was responsible for evaluating the refinery's power and steam needs and for recommending the building of additional generating capacity.

George P. MacKnight has joined the Public Relations Department of Standard Oil Co. (Indiana) as advanced writer. Formerly office manager of the Chicago Motor Club's Public Relations Department, he also has been with the National Safety Council, Sears, Roebuck and Company, Porcelain Enamel Institute, *American Peoples Encyclopedia,* Bloomington, Ind., *Star-Courier* and Fort Wayne, Ind., *Journal-Gazette.*

Charles A. Cogan has been appointed assistant manager of the Operations Division, Manufacturing Department, Standard Oil Co. (Indiana). He was assistant manager of the company's Cas-

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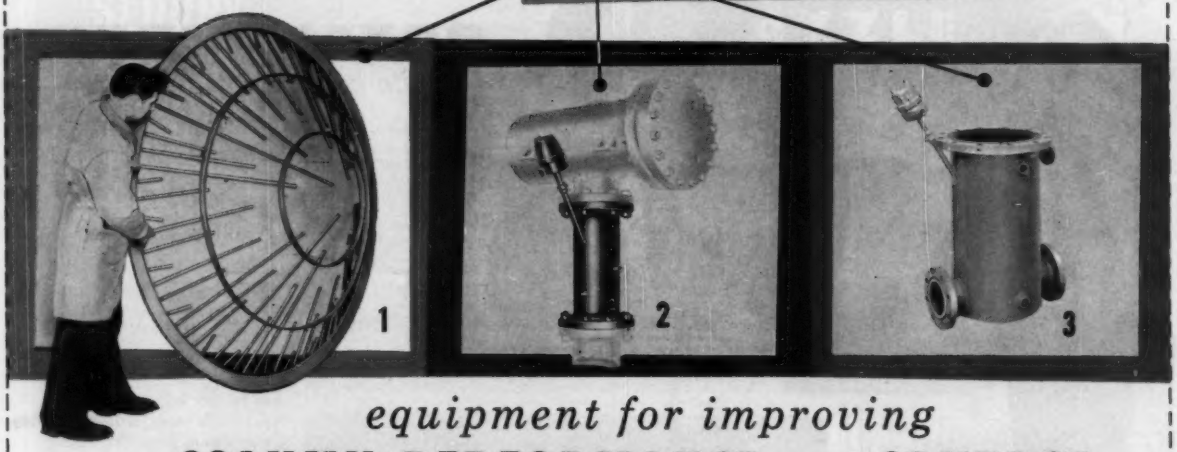

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ALSO AVAILABLE: Packing support plates, distributor plates, stills, columns, and complete distillation plants.

FURTHER INFORMATION AVAILABLE ON REQUEST

All items above are patented.

DISTILLATION ENGINEERING COMPANY 110 DORSA AVENUE, LIVINGSTON, N. J.

COLORS *in fluid form*

DYE CONCENTRATES*

for cleaner, easier coloring of petroleum products; eliminate pre-dissolving, dusting, operator exposure • less skill and equipment required; introduced directly into finished product • the answer to bulk, tank, truck, tank car, barge, terminal and pipeline coloring • can be used with dry dye eductor equipment • use of dye concentrate involves no additional cost compared to ordinary dry dyes.

PATENT CHEMICALS, INCORPORATED

MANUFACTURERS OF DYES AND CHEMICALS FOR THE PETROLEUM INDUSTRY

Pioneers in Petroleum Dyes

FOR USE IN
Gasolines
Diesel Fuels
Fuel Oils
Lubricating Oils
Automatic Transmission Fluids
Break-in Oils and Greases

Also Available in Dry Dye Form.

Dye concentrates can be prepared to specifications.

Samples and description upon request.

CALL US COLLECT FOR FAST ACTION
PHONE MUlberry 4-1726-7

NOTE: — *Reds — Yellow — Orange — Blue — Meet Mil-F-5572 Specifications*

*Patent Pending

PATENT CHEMICALS INC.
Manufacturing Division: 335 McLean Blvd., Paterson 4, New Jersey

PATENT FUELS & COLOR CORP.
Marketing Division: 2410 Carew Tower, Cincinnati 2, Ohio

For more data on advertised products, use Readers' Service Cards, last page.

Men . . .

per, Wyo., refinery before transferring to the Chicago general office. With Standard since 1934, Cogan was appointed assistant manager of the Casper refinery in 1952. He graduated from Colorado College and received his M.S. degree in chemical engineering from Massachusetts Institute of Technology.

J. Prince Warner, general manager of manufacturing, has been elected a vice president of Esso Standard Oil Co. He had been general manager of manufacturing since January, 1956, and was formerly general superintendent of the Baltimore and Baton Rouge refineries and assistant general manager, Baton Rouge. With Esso Standard since 1929, Warner is a graduate of Massachusetts Institute of Technology and was on the instructing staff there before joining the company.

Warner

T. Q. Eliot has been named manager, Process Development Department, Texas Butadiene & Chemical Corp., Houston. He was formerly head of the company's Process Technical Service Department.

Ben A. Burdette has been named mechanical engineering supervisor at Socony Mobil Oil Co.'s Augusta refinery. He began work there in 1945 and was with the Engineering Department until he became Stores Department manager in 1953. In 1955, he was appointed chief project engineer and April 1, 1958, became assistant employe relations manager.

Joseph G. Evans and **James G. McIlhiney** have been named managers of the Cleveland and San Francisco district offices, respectively, of E. I. du Pont de Nemours & Co.'s Petroleum Chemicals Division. Evans had been manager of the San Francisco district office for the last five years while McIlhiney most recently had been a sales representative in San Francisco.

Harry Oliver Cameron, 89, former Sun Oil Co. executive who retired in 1955, died July 29 at Toledo Hospital. At the time of his retirement, he was assistant secretary of the company, and assistant to the vice presidents in charge of manufacturing and production.

Dr. Norbert A. Goeckner has joined the staff of Whiting Research Laboratories, Standard Oil Co. (Indiana) to do research in new methods for analyzing petroleum and petroleum products. He has M.S. and Ph.D. degrees in chemistry from the State University of Iowa.

Dr. H. Roswell Jones has been named staff engineer, main office, The H. K. Ferguson Co. He received his B.S. and Ph.D. degrees in chemical engineering from Johns Hopkins University. Previously, Dr. Jones was with Arthur G. McKee & Co. and Blaw-Knox Co. as a process engineer.

Clifton C. Garvin, Jr., has been named assistant general manager of the Esso Standard Oil Supply Department, Co., New York. Garvin, who joined the company when he received his M.S. degree in chemical engineering in 1947, has been operating superintendent, Baton Rouge Refinery. He began his career with Esso as an engineer in the Baton Rouge Refinery Process Engineering Department, and was successively group head of process engineering, assistant (and later head), Chemical Technical Service Department, Crude & Product Coordination Department, head of the Chemical Products Division, and operating superintendent.

Garvin

Dr. Kenneth J. Radimer has been named a research chemist, The M. W. Kellogg Company, New York. He will work with the Exploratory Research Group at Kellogg's laboratories, Jersey

LITTLE TAG . . . BIG MEANING!
Not a mere name plate, this little metal tag on a piece of equipment is unreserved assurance of quality workmanship and dependability of service . . . priceless characteristics not solely measured in dollars and cents.
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You'll want Full Line Catalog A-9 for engineering data and specifications.
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THE MACK IRON WORKS COMPANY
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SPECIALISTS TO PETRO-CHEM-REFINING AND CHEM-PROCESS INDUSTRIES SINCE 1901
Stock and custom made items for many engineered applications which involve pumping of fluid materials and operational liquids.
BLINDS • SPACER RINGS • STRAINERS • PIVOT FLANGES

for this type service . . . specify this STRONG *trap:*

Dirty Lines or Dirty Steam:

Lowest Initial Cost per pound capacity:

Lowest Initial Cost per pound weight:

Eliminating Large Volumes of Air:

HYDRO-FLEX INVERTED BUCKET TRAP

FLOAT & THERMOSTATIC TRAP

Low Pressures with some air elimination:

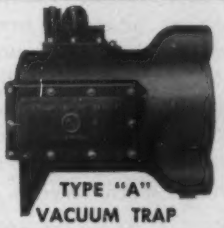
Pulsating or Widely Varying Pressures:

OPEN BUCKET TRAP

Continuous flow required:

BALL FLOAT TRAP

Draining a line carrying a vacuum discharging to atmosphere:



TYPE "A" VACUUM TRAP

Draining a line carrying a vacuum or very low pressure discharging against a hydrostatic head or back pressure:

TYPE "M" VACUUM TRAP

on every type service STRONG steam traps give you longer life, less maintenance

Strong offers six types of steam traps to answer every requirement for removing condensate from all types of systems.

You can specify these Strong Traps with the assurance that you will get maximum service life. Proof is the fact that replacement parts are still being ordered for traps sold 50 years ago!

Here are some low maintenance features built into Strong Traps. Screwed-in, replaceable valves and seats of wear-resistant ANUM-METL. Deep-drawn, one-piece stainless steel buckets. Extra-heavy body and cover construction. Thorough testing. Interchangeable parts.

You will be money and years ahead when you specify Strong Traps. For further information, contact your local Strong distributor — he carries complete stocks and replacement parts, offers prompt service.

Selector Chart in Strong Catalog No. 69A gives trap recommendations for 45 types of equipment. Write for your copy or call your distributor.

4/S

STRONG, CARLISLE & HAMMOND

508 Sandusky Street • Conneaut, Ohio

steam traps • air traps • float traps • vacuum or pumping traps
F and T traps • continuous blowdown valves • separators • engine stops

For more data on advertised products, use Readers' Service Cards, last page.

MOST COMPLETE LINE

Eleven Product Groups
Serve Every Sealing Need

GROUP NO. 3

Rotary Pump Packings

Belmont offers 22 different Packings for centrifugal and rotary pumps—to answer the wide variety of requirements of this important packing application. Constructions include braided long fibre Canadian and blue African Asbestos, copper and lead inserted asbestos, cotton, flax, Teflon yarn and molded shredded-Teflon pump packing rings. Lubricants include special oil and solvent impervious compounds for petroleum products, non-staining lubricants for paper mill service, edible lubricants for food plant services, Teflon suspensoid for positively non-contaminating services in dairy, food and chemical services.

In addition, Belmont offers the "Chemical" Seal—a rotating mechanical seal of pressure-balanced Teflon Bellows design with greater immunity from corrosion, and longer useful life than any other design.

See your Belmont Distributor or write for the name of one nearest you.

OTHER BELMONT PRODUCT GROUPS

1. High Pressure Asbestos Packings
2. Valve Stem Packings
4. Criss-cross Braided Packings
5. Hydraulic Packings
6. Bel-Vee V-Rings
7. Sheet Packings
8. Gaskets
9. Metallic Packings
10. Plastic Packings
11. Expansion Joints

MOST CONVENIENTLY AVAILABLE

Nationwide Industrial Distributor Organization Provides On-the-Spot Service

BELMONT

The Belmont Packing and Rubber Company
Butler & Sepviva Streets, Phila. 37, Pa.

Men . . .

City, N. J. Holder of a Ph.D. degree in organic chemistry, Dr. Radimer was formerly with CBS Laboratories, Stamford, Conn.

Dr. H. A. Holcomb has been promoted to research specialist, Humble Oil & Refining Co.'s Research and Development Division, Baytown. He is now serving in the company's Executive Development Program in charge of the section engaged in research on corrosion, waste disposal and electric discharge reactions. Dr. Holcomb holds a B.S. degree in chemical engineering from Texas Technological College and M.S. and Ph.D. degrees from The University of Texas.

Holcomb

Dr. Eugene E. Richardson has been named a senior project chemist at Whiting Research Laboratories, Standard Oil Co. (Indiana). Since he joined Standard in 1951, he has done research in developing special lubricant materials and in finding new applications for petroleum waxes. Dr. Richardson has B.S. and M.S. degrees in chemistry from North Texas State College and a Ph.D. degree in chemistry from Kansas State College.

Eric S. Pfefferkorn has been named manager, personnel and labor relations, The California Oil Co. He joined Caloil in 1956 after 20 years in petroleum marketing with Standard Oil Co. of Calif. Pfefferkorn is a member of the Industrial Relations Counselors Alumni Association.

John E. Anderson has been named a project chemical engineer at Standard Oil Co. (Indiana) Whiting, Ind., research laboratories. Others appointed to the post are **Arthur W. Larson, Gustav Warner, Jr., Charles D. Kalfadelis, George M. Wilmsen, Paul H. Schwann, Wilmer M. Duvall, Manoj K. D. Sanghvi, Guy J. Walker** and **John M. Coopersmith.**

Claude C. Katchelor has been named vice president in charge of fuels sales, General Asphalts, Inc., Oklahoma City. He was formerly sales manager of the company's Minneapolis office.

Marvin L. Buckler has been named a process engineer to work in refinery and chemical plant design for Badger Manufacturing Co., Waltham, Mass. He has a B.S. degree in chemical engineering from the University of Pittsburgh.

Dr. Frank Slezak has been named group leader of the Polymer section of Diamond Alkali Co.'s Research department. He joined Diamond in 1954 after studying organic chemistry at Oklahoma A & M, where he earned M.S. and Ph.D. degrees. He worked for leading chemical

Right you are, the photograph was faked. As with prefabricating and installing critical piping, a genuine performance requires an experienced specialist. Write for our "Brochure" of shop and field facilities, and on your next high-temperature, high-pressure piping job . . . ask us in.

W. K. MITCHELL & CO., INC.

Philadelphia 46, Pa.

WESTPORT JOINT
(PATENTED)

MITCHELL PIPING
SINCE 1899

PIPING FABRICATORS AND CONTRACTORS

For more data on advertised products, use Readers' Service Cards, last page.

Men . . .

firms as a student at Antioch College while earning a B.S. degree in chemistry. He later became a research chemist in Diamond's Organic section. Dr. Slezak is a member of American Association for the Advancement of Science, ACS, Phi Lambda Upsilon, Sigma Xi and Diamond Technical Society.

John C. Anderson has been named controller-treasurer, The Vickers Petroleum Co., Wichita. He had been controller of the company since 1958.

Dr. George G. Oberfell of Bartlesville, the chemist who played a primary role in the development of liquefied petroleum gas as domestic and industrial fuels, will receive the Walton Clark Medal from The Franklin Institute. The former Phillips Petroleum Co. executive will be awarded the medal at formal Institute ceremonies, Wednesday, October 21.

Oberfell

The medal citation to Dr. Oberfell reads: "In consideration of his significant contributions to the development of liquid petroleum (LP) gas as a source of domestic fuel."

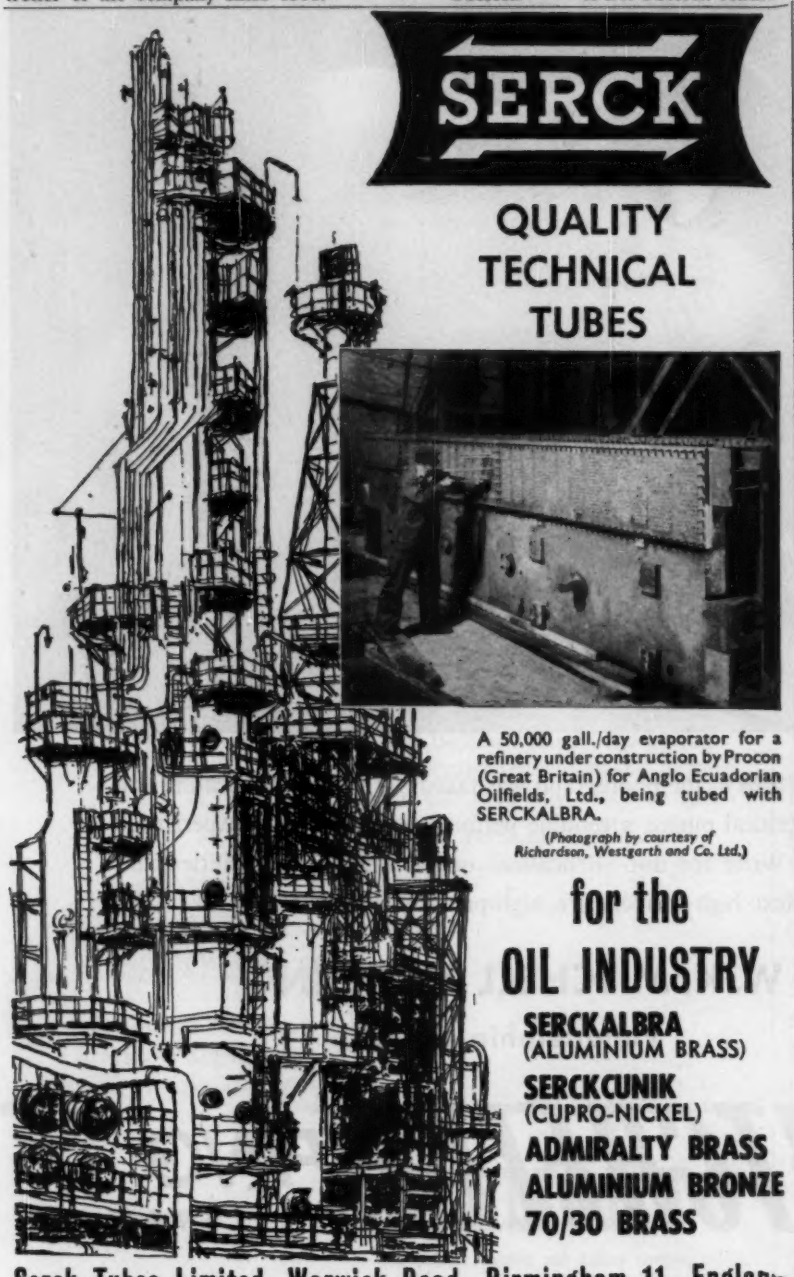
Under Dr. Oberfell's direction, research at Phillips Petroleum Co. laboratories resulted in the following contributions to the petroleum and chemical industry: manufacture, distribution, marketing and use of liquefied petroleum gases; charcoal adsorption as a testing method for gasoline extraction; development and improvement of oil absorption natural gasoline extraction processes; low temperature fractional analysis of low boiling hydrocarbons; isomerization of paraffins; and catalytic cracking and reforming processes for improving yield of products from gas and oil.

Dr. Oberfell holds 33 patents, is author of numerous technical articles and is coauthor of two books, "Natural Gasoline," 1924, and "Natural Gasoline and the Volatile Hydrocarbons," 1948. The Clark Medal, which he will receive, was founded in 1926 by the United Gas Improvement Co. of Philadelphia in honor of Walton Clark, then vice president of the Gas Co. who had served as president of The Franklin Institute from 1907-1923. The medal is awarded by the Institute to the author of the most notable advance in knowledge or improvement in apparatus or in method concerning the science or the art of gas manufacture.

George T. Atkins has been retained by Foster Wheeler Corp. as a full time consultant in the fields of petroleum refining and petrochemical processing. His specialty is process design of distillation, heat transfer, fluid catalytic cracking, extractive distillation and waste heat recovery facilities. In his 29 years with Humble Oil & Refining Co., Atkins engaged in outside consulting work and authored numerous articles for leading technical journals. He holds a number of patents, several of which are currently featured in commercial units. A member of AIChe and ASME, he is active in the ASME Technical Committee on Unfired Heat Transfer Apparatus and is chairman of the Users Sub-Committee. A graduate of Washington University, Atkins has resided in St. Louis, Dallas and Baytown, Texas, where he will continue to live.

M. James Campbell has been named assistant to the vice president of Allied Chemical Corp.'s Solvay Process Division. Succeeding Campbell as manager at Syracuse will be **Robert B. Lautner,** currently manager of Solvay's Moundsville, W. Va. operations. Moving to Moundsville as manager will be **Robert E. James,** who has been manager of Solvay's Baltimore, Md. plant. With the assumption of greater responsibility by James at Solvay's complex Moundsville plant, the Baltimore plant will be under the direction of **Edward J. Walsh,** assistant manager.

Campbell is a graduate of Lehigh University with a degree in chemical engineering. He has been a Solvay employee since 1939 and held a variety of supervisory posts in Solvay's Syracuse plant culminating in his appointment as man-



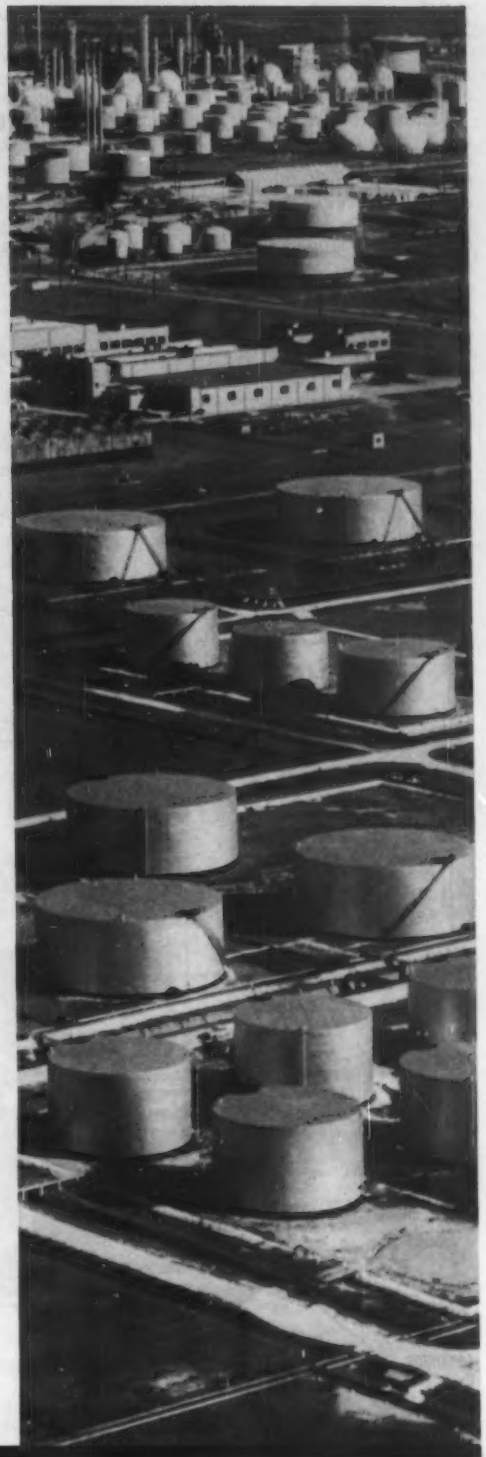
A 50,000 gall./day evaporator for a refinery under construction by Procon (Great Britain) for Anglo Ecuadorian Oilfields, Ltd., being tubed with SERCKALBRA.

(Photograph by courtesy of Richardson, Westgarth and Co. Ltd.)

For more data on advertised products, use Readers' Service Cards, last page.

Oakite ECP
engineered cleaning program

saves costly refinishing of storage tank



Bunker C spillage at a brand new refinery virtually blanketed the riveted sheet aluminum jacket on a storage tank. The hardened oil was not only unsightly, but posed a possible fire hazard. Fortunately, before the aluminum was replaced, the Oakite man was called in. Analyzing the situation, he added a new page to the ECP*. It called for prespraying the tank with Oakite 8 to soften the hardened asphalt-like deposits . . . then steam cleaning with aluminum-safe Oakite 93 using the Oakite Hurriclean steam-detergent gun.

In less than two days, all of the hardened crude was gone, the tank shone bright as new, the refinery saved the cost of installing new reflective insulation.

WHAT IS OAKITE ECP*? ECP stands for Engineered Cleaning Program*. It's a program of chemical cleaning developed for your refinery, your equipment, your conditions, your through-put. It itemizes the problems, and the methods and materials to solve them. It puts the chemistry of cleaning to work for your benefit. It's supervised by a refinery-experienced Oakite specialist. Before your next turn-around, call the Oakite office nearest you, or send for free bulletin. Oakite Products, Inc., 50B Rector Street, New York 6, N. Y.

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50 1909-1959 SCIENCE
years' leadership in industrial cleaning

Export Division Cable Address: Oakite

Technical Service Representatives in Principal Cities of U. S. and Canada

Oakite ECP
your economy key

For more data on advertised products, use Readers' Service Cards, last page.

Men . . .

ager in January, 1958. He will be located at Solvay's New York executive office.

Lautner is a native of Michigan. He is a graduate of Louisiana State University with a degree in mechanical engineering. He first came to work for Solvay in 1947 as a technical assistant at the Baton Rouge plant. He was transferred to the Moundsville plant as assistant manager in 1956 and was made manager of that plant the following year.

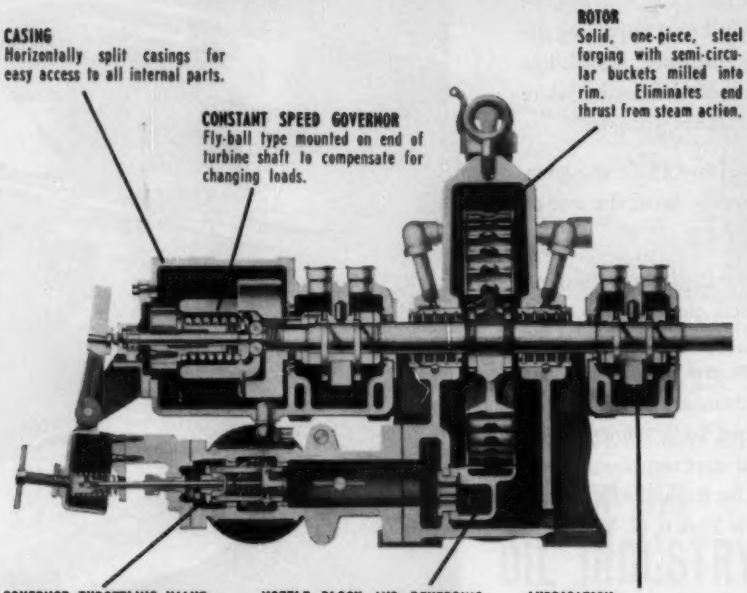
James is a graduate of the University of Nebraska with a B.S. degree in chemistry. In 1940 he was employed by Allied Chemical's General Chemical Division, Delaware works. In February, 1948, he became production supervisor at Solvay's Chromium Chemicals plant in Baltimore and was named manager of the plant in October, 1957.

R. H. Hord, manager of personnel and industrial relations at Shell Oil Company's Wood River, Ill., refinery, will become manager of the same department for Shell Pipe Line Corp. in Houston. He joined Shell at the Wood River refinery in 1926, and later served in the Personnel and Industrial Relations Departments at St. Louis and Houston. He returned to Wood River in 1940 and five years later became manager of the Personnel and Industrial Relations Department there.

Whiton

PRECISION ENGINEERED STEAM TURBINES

For almost 50 years, Whiton has combined experience, workmanship and **precision engineering** in building high quality, reliable steam turbines for all types of power and drive applications. Whiton horizontal, helical-flow, single stage turbines are available in 8 wheel sizes. Axial-flow, Curtis-blade turbines are also available. Write for complete data on Whiton's horizontal and vertical turbines.


CASING
Horizontally split casings for easy access to all internal parts.
CONSTANT SPEED GOVERNOR
Fly-ball type mounted on end of turbine shaft to compensate for changing loads.
ROTOR
Solid, one-piece, steel forging with semi-circular buckets milled into rim. Eliminates end thrust from steam action.
GOVERNOR THROTTLING VALVE
Double-seated, balanced V-ported. Admits steam to assure stability control as load varies.
NOZZLE BLOCK AND REVERSING CHAMBER
One-piece unit. 2, 3, or 4 re-directing buckets as required for maximum efficiency.
LUBRICATION
Water cooled oil ring lubrication.

MAXIMUM OPERATING SPECIFICATIONS

POWER	to 1200 HP
SPEED	to 8500 RPM
STEAM PRESSURE	to 1250 PSIG
STEAM TEMPERATURE	to 1050° FTT

THE WHITON MACHINE COMPANY
NEW LONDON, CONNECTICUT

Dr. Ford H. Blunck has been appointed manager of the Planning Division, Manufacturing Department, Standard Oil Co. (Indiana). Formerly manager of the Unit Operations Division, he succeeds **Charles F. Smith,** who has become director of purchases for the company. Dr. Blunck joined Standard's Whiting, Ind., research laboratories in 1936 and became a technical service group leader in 1940. In 1945 he transferred to the Manufacturing Department at the Whiting refinery and became general foreman of pressure stills. In 1949 he advanced to assistant superintendent of the Light Oils Division. He was named superintendent of the Projects Division at Whiting in 1950. In 1951 he was advanced to manager of the Projects, Capital Expenditures, and Miscellaneous Contracts Division in the General Office Manufacturing Department, Chicago. He became general superintendent of Standard's Wood River, Ill., refinery in 1952, and returned to the general office in 1956 as manager of the Unit Operations Division.

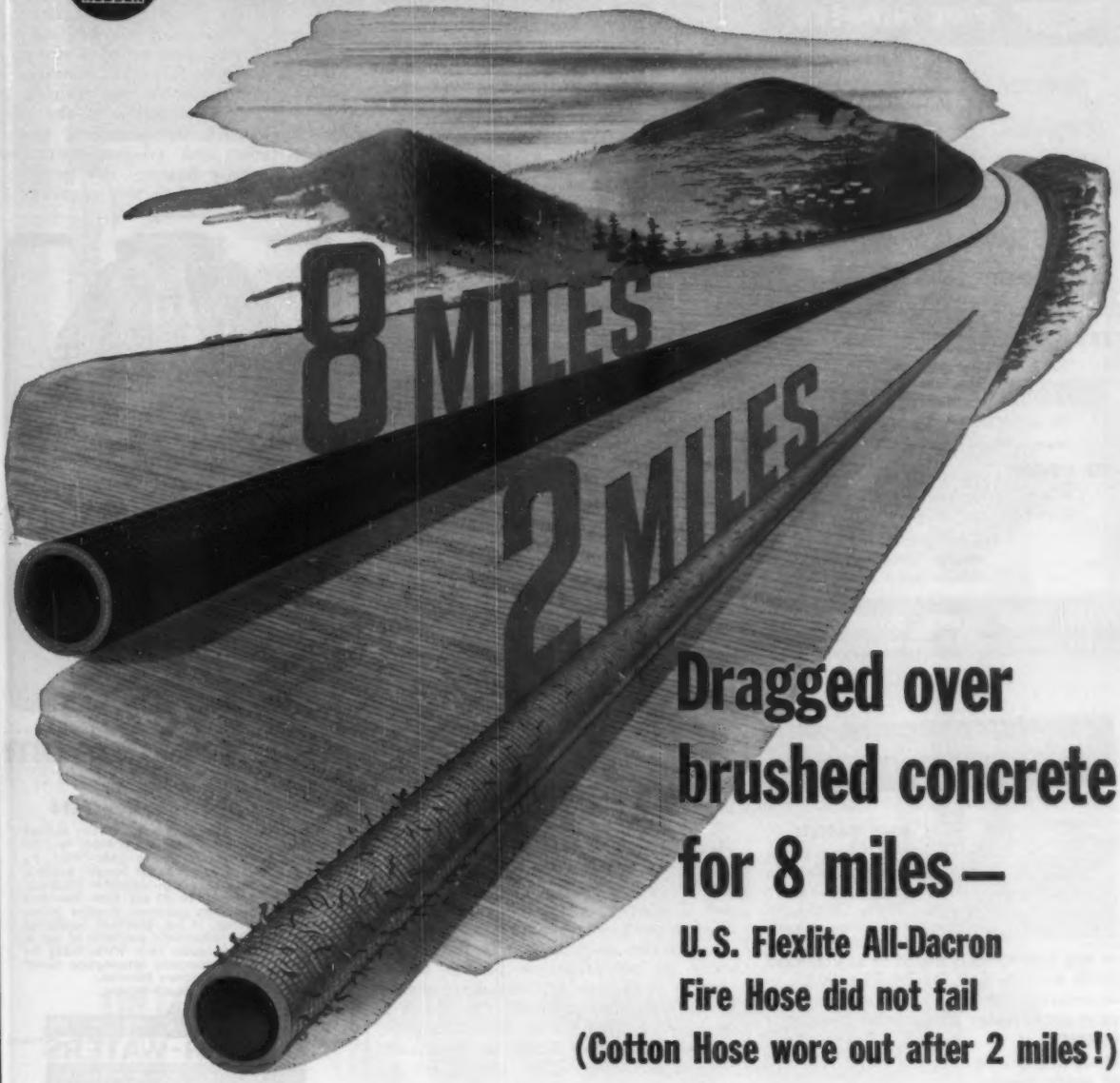
E. A. Hugill, Jr., has been elected secretary of Shell Oil Co. He was also appointed secretary of Shell Chemical Corp., International Lubricant Corp., and Shell Canadian Exploration Co. He succeeds **J. A. Horner** as secretary of those companies. Hugill was also appointed a vice president of Shell Development Co. and will succeed Horner as vice president in charge of the Licensing Division later in the year.

Hugill

Hugill, who received his A.B. and LL.B. degrees from the University of California, joined Shell in 1933 as a law clerk in the San Francisco office. He became an attorney there in 1936 and, after serving at various locations, was appointed general attorney of the company in the New York Legal Department, July 1954.

F. L. Fagan, president of LPGA, has announced the names of chairmen for the 19 standing committees and six sections of the organization. The appointees also become members of the group's board board of directors. They will serve one-year terms. Committee chairmen are: **G. R. Postlewait,** Framgas, Inc., Chagrin Falls, Ohio, Appliance Specifications; **L. A. Brand,** Empire Stove Co., Belleville, Ill., Constitution and Bylaws; **W. R. Sidenfaden,** Suburban Gas Service, Inc., Pomona, Calif., Convention Committee; **K. H. Koach,** Green's Fuel, Inc., Sarasota, Fla., Distinguished Service Award; **C. E. Blome,** Wm. Wallace Co., Dallas, Educational; **A. B. Ritzenthaler,** Tappan Co., Mansfield, Ohio, Finance; **C. A. Childers,** Sungas Distributors, Raleigh, N. C., Gas Fuel Technology; **J. W. Martin,** Shamrock Oil & Gas Corp., Amarillo, Texas, Gas Unity; **L. E. Nyberg,** Western Propane Co., Batavia, Ill., Insurance; **J. A. Storm,** Sinclair Oil & Gas Co., Tulsa, Legislative; **Frank Perry,** Cities Service Oil Co.,

FLEXLITE ALL-DACRON FIRE HOSE



Dragged over brushed concrete for 8 miles—

U. S. Flexlite All-Dacron Fire Hose did not fail

(Cotton Hose wore out after 2 miles!)

This test convincingly proves the overwhelming ruggedness of Flexlite® Hose. It demonstrates, too, that a hose can be rugged and at the same time light and *flexible*. Flexlite's lightness enables fire crews to fight fire without being hampered by excess weight.

U.S. Flexlite Hose brings you these other advantages: It won't absorb water and hence can't freeze. It is highly resistant to oils and chemicals. Every foot is subjected to five hundred pounds test pressure before leaving the factory.

This hose comes in any color for ready identification as a fire hose. This prevents its being carried off or utilized for purposes other than fire fighting.

• • •

When you think of rubber, think of your "U.S." Distributor. He's your best on-the-spot source of technical aid, quick delivery and quality industrial rubber products.

Mechanical Goods Division

United States Rubber

WORLD'S LARGEST MANUFACTURER OF INDUSTRIAL RUBBER PRODUCTS

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NPW Packaged PIPE NIPPLES

Famous for fast complete shipments

Seamless Steel Pressure Tube Nipples

A.S.T.M. A-83 and A-106

FROM STOCK:

⅛" to 1½" Standard and Extra Strong Weights, Black Grade "A."

½" to 1½" Double Extra Strong Weight, Black, Grade "A."

TO ORDER:

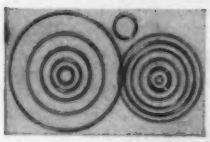
Grade "B," Galvanized, Cold Drawn in Larger Sizes.

• *Avoid errors. Nipples are marked "SMLS" with Grade, Weight and A.S.T.M. Spec.*

ID-3

Pittsburgh NIPPLE WORKS, Inc.
1455 SPRING GARDEN AVE., PITTSBURGH 12, PA.

For Dependable GASKETS
Specify CHICAGO-WILCOX



RING GASKETS

For ring-type flanged joints in high pressure lines. Made of soft iron, standard steel alloys or any non-ferrous metal to any desired cross section. Ask for Bulletin 563.

HEAT EXCHANGER GASKETS

Made in any size or shape needed in double-jacket type. Also cut from solid metal or sheet packing. Ask for Bulletin 564.

CORRUGATED METAL GASKETS

Plain or jacketed type. Made of ingot iron, aluminum, stainless steel, copper, brass, nickel and monel in all sizes and shapes. Ask for Bulletin 565.

Prompt Deliveries

7719 S. Avalon
Chicago 19, Ill.

CHICAGO-WILCOX MFG. CO.

Men . . .

Bartlesville, LP-Gas Specifications; **C. J. Bender,** Trinity Steel Co., Dallas, Market Research; **C. O. Russell,** Thermogas Co., Inc., Des Moines, Planning & Organization; **D. B. Barton,** Skelly Oil Co., Kansas City, Publicity & Publications; **W. A. Schuette,** Hausgas, Inc., Washington, Mo., Safety; **Paul Tucker,** Phillips Petroleum Co., Bartlesville, Technical & Standards; **F. A. Shellhorn,** Anchor Petroleum Co., Tulsa, Transportation; **J. D. Lay,** Marshall Butane Gas & Appl. Co., Inc., Albertville, Ala., Membership; **W. A. Naumer,** Pyrofax Gas Corp., New York, National Affairs.

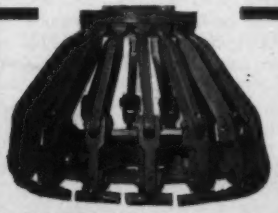
LPGA has also appointed a slate of section chairmen. These men head occupational groups within the association. They are: **Reeves Brown,** Hardwick Stove Co., Cleveland, Tenn., Appliance Manufacturers; **M. B. Gault,** Robertshaw-Fulton Controls Co., Youngwood, Pa., Equipment Manufacturers; **J. H. Williams,** The Weatherhead Co., Cleveland, International; **Charles Francisco,** Fuelane Corp., Liberty, N. Y., Marketers; **C. M. Mockler,** Shell Oil Co., New York, Producers; **Richard Meisenbach,** J. B. Beaird Co., Shreveport, La., Tank Fabricators.

Dr. William E. Bonnet has been named technical assistant to Sun Oil Co.'s director of research and development. **James F. Dempsey** replaces Dr. Bonnet as section chief, petrochemicals, in process development, and **Howard R. Moyer** and **Richard P. Barbor** have been named assistants in polypropylene development work.

Dr. Bonnet graduated from Drexel Institute of Technology with a B.S. degree in chemical engineering in 1947. He received his M.S. degree in 1948 and his Ph.D. degree in 1950, both from the University of Delaware. Joining Sun Oil in 1950 as a research engineer in research and development, he became a section chief in process development in 1953. His most recent assignment was the supervision of polypropylene process development at the research and development laboratory, Marcus Hook, Pa. He is a member of AIChE and ACS. Dempsey, a 1953 graduate of Columbia University with a B.S. degree, he joined Sun in 1953 as a research engineer in research and development.

W. R. Barker, a civil engineer, has joined the Technical Division, Humble Oil & Refining Co., Baytown, Texas. Other new men who have joined the division are **J. O. Ogletree,** civil engineer; **T. F. Clark, J. A. Pace** and **L. W. Stasney,** mechanical engineers; **J. H. Harding** and **M. J. Larsen,** electrical engineers; **J. R. Beissel, E. C. Chauviere, R. P. Larkins, P. Z. Larson, D. T. Lomax, J. B. Mabry, Marilyn McEver, C. E. McLees, M. A. Moore, R. E. Payne, T. H. Ross, J. H. St. Clair** and **G. M. Sewell,** chemical engineers; and **J. S. Chalsty** with degrees in chemistry, physics and business administration. **T. M. Campbell,** a chemical engineer, has returned to the division from military service.

Dr. John G. McLean and L. C. Peters, both of Houston and both vice presidents of Continental Oil Co., have been promoted to new executive positions with the company. McLean, vice president in charge of coordinating and planning, has been promoted to vice president in charge of financial and transportation activities. In his new position, he will assume the direction of the company's financial, transportation, marine transportation and aviation operations. Peters, formerly financial vice president, has been promoted to vice president in



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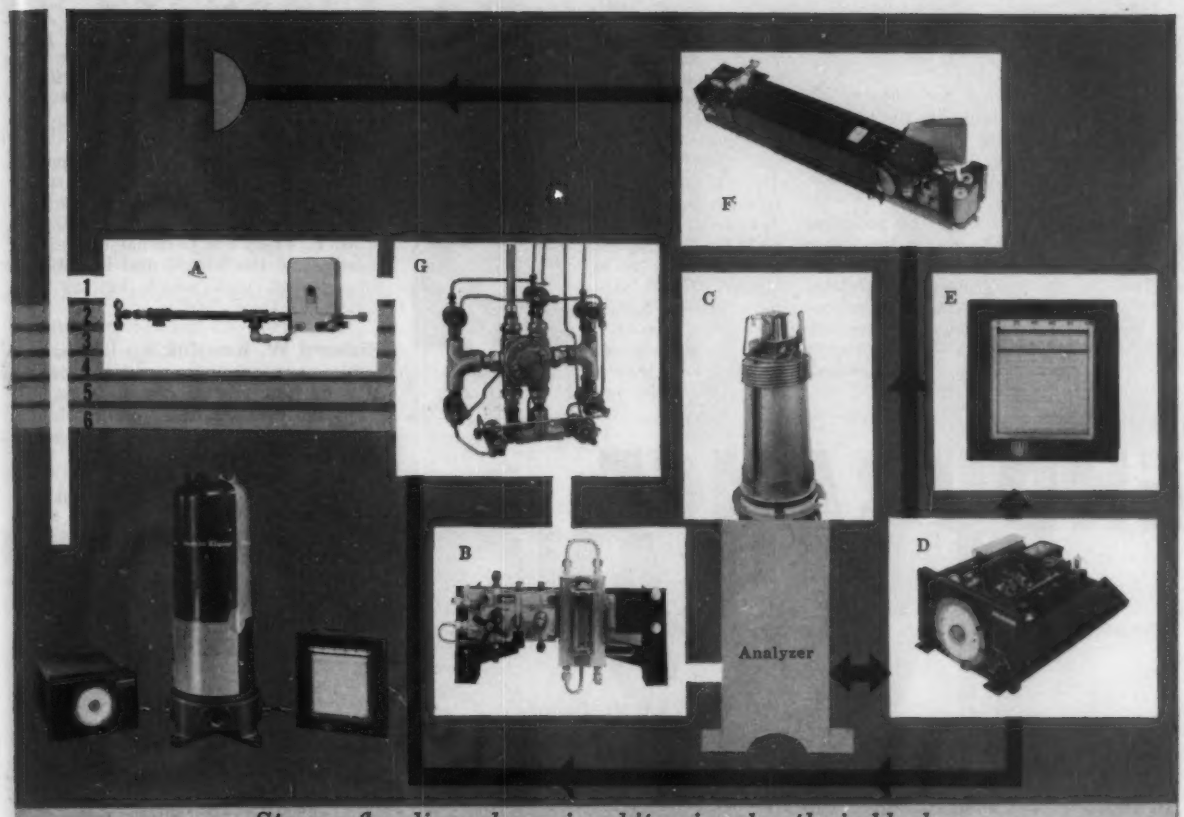

Stream flow lines shown in white, signal paths in black

This block diagram shows how six process streams can be selectively analyzed by the P-E Model 184-B. For brevity, Stream #1 only will be followed through the system.

Stream #1 is tapped, and the sample vaporized in the Liquid Sample Vaporizer (A). Sample #1 then flows (with the other five vaporized samples) into the enclosed, heated Multi-Stream Solenoid Switching Manifold (G). The solenoids are electrically directed by the Programmer (D). As it is selected, Sample #1 is valved into the Final Sampling Assembly (B), where it is filtered and metered into the Analyzer. The Analyzer quantitatively and qualitatively separates the sample's components by gas chromatography, produces signals which appear as a bar graph on Recorder (E).

The signal can also be fed into a Pneumatic Control Accessory (F) which produces a 15 psi signal for automatic control of one variable component of the stream.

The Analyzer with Reverse Flow Valve (C) allows for the analysis of light components individually plus a "total heavies" measurement; it back-flushes and analyzes heavy ends as a single peak, shortening analysis time in the process. The Programmer (D) is available in a variety of modes for multi-component and multi-stream analysis. It controls the Switching Manifold (G) and the Analyzer, and the read-out of the Recorder (E).

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INSTRUMENT DIVISION

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For more data on advertised products, use Readers' Service Cards, last page.

Men . . .

charge of coordination and supply. He will assume responsibility for the Coordinating and Planning Department and Conoco's pipe line, crude oil trading, product supply and product distribution activities.

McLean was elected a vice president of Conoco in 1956, following two years service as a company consultant while on leave of absence from Harvard University. He is a graduate of the California Institute of Technology and received both his M.B.A. degree and Ph.D. degree in commercial science from Harvard University.

John W. Gendron has been named general manager of transportation and supply for Richfield Oil Corp. He will be responsible for activities of the Supply and Distribution, Marine, and Pipe Line Departments. Gendron moved to Richfield from Tidewater Oil Co., where his last post was as assistant general manager of the Eastern Division. Prior to that, he was assistant to the president at Tidewater. He served as director of Iricon Agency, Ltd., and was its president in 1956-57. He attended the University of Oregon and the University of San Francisco Law School, and is a member of API and the Petroleum Club of Los Angeles.

Gendron

F. B. Behrens will be assistant general manager of transportation and supply while continuing as manager of the Supply and Distribution Department.

M. E. Tracy has been named assistant manager of the Supply and Distribution Department, with which he has been connected since 1950.

Richard W. Keusink has been named public relations representative for the Western Oil and Gas Association. He was formerly director of public relations for McNeil Construction Co., and before that was news director of KTLA Television Station, Hollywood.

During the Korean War Keusink was press briefing officer at general headquarters, Far East Command, Tokyo, and was United Nations press representative at the peace talks at Kaesong and Panmunjom, Korea. He was also Public Information Officer of the 24th Infantry Division in Korea. A former newspaper man, Keusink has held editorial positions on the *Santa Paula Chronicle, Saticoy Journal, Burlingame Advance* and the *Redwood City Tribune*. He is a graduate of Stanford University.

Dr. L. G. Massey has been named head of Universal Oil Products Co.'s Computer Department, Des Plaines, Ill. A graduate of the University of Wisconsin, he joined Universal's Pilot Plant Division in 1951. In 1957 he was appointed assistant head of the Computer Department.

Malcolm Gish has been named assistant superintendent of Phillips Petroleum Co.'s Western District, with headquarters in Odessa, Texas. **W. G. Copenhaver** becomes district engineer, Western District. **H. R. Harris** has been named district engineer for the Panhandle District with headquarters in Borger.

Gish, a graduate of the University of Wyoming, started with Phillips in 1941. He has been district engineer for the Panhandle District since June 1958. Co-

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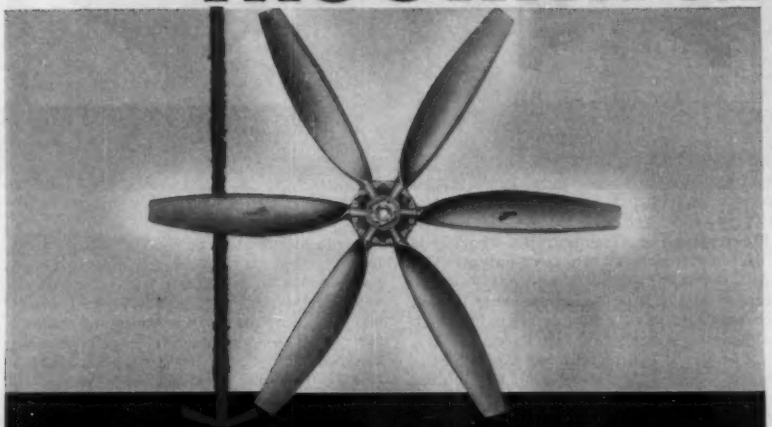

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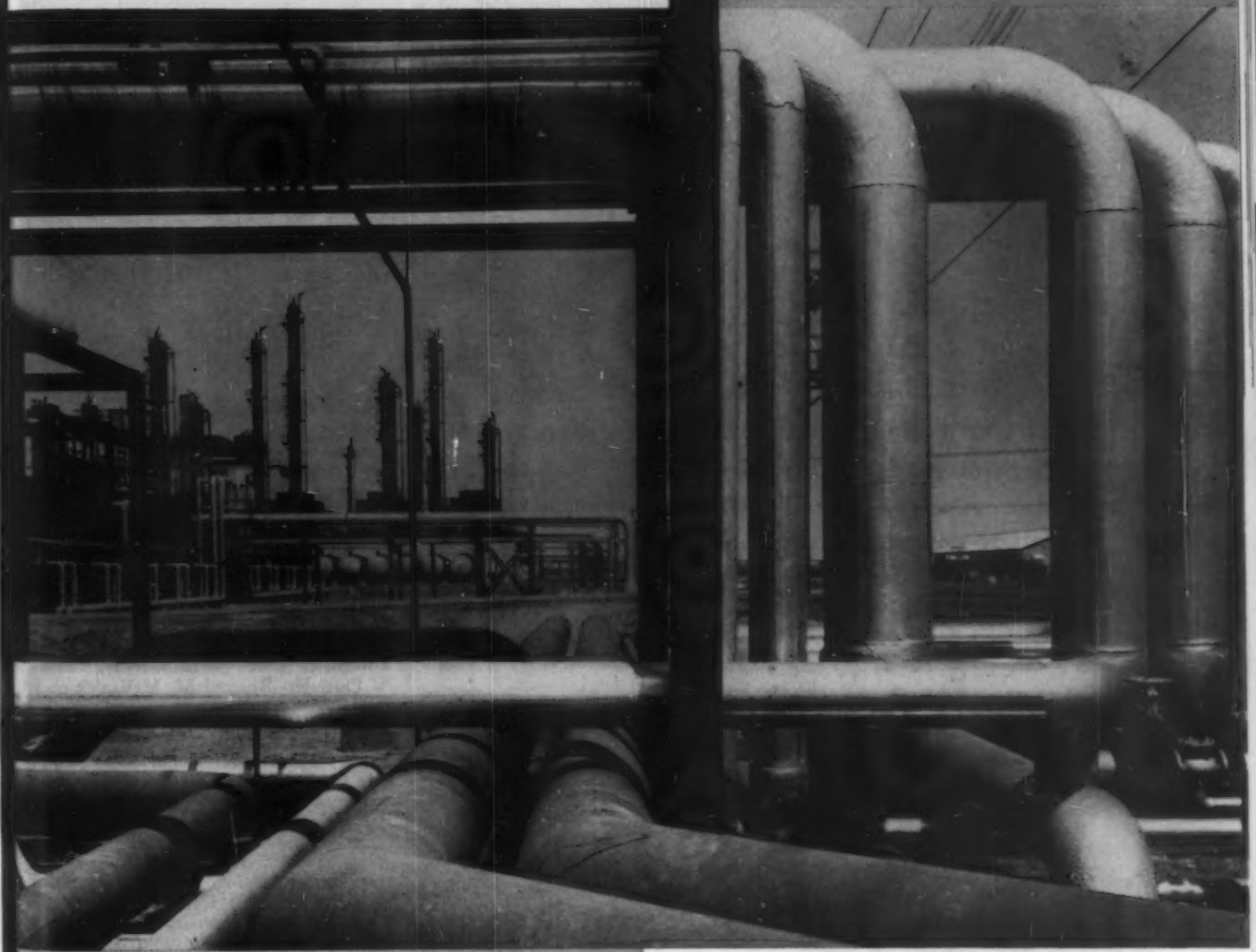

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Men . . .

penhaver, a graduate of the University of Oklahoma, started with Phillips in 1946, and has been assistant district engineer at Borger since 1956. Harris graduated from the University of Kansas, started with Phillips in 1941, and has been district engineer for the Western District since June 1958.

Howard Phipps, Jr., has been elected to the board of directors and the executive committee of Western Petrochemical Corp. A graduate of Harvard, he is with the Bessemer Securities Corp., an investment holding firm.

Albert E. Ernst has been elected a vice president of Continental Oil Co., effective October 1. He will be in charge of developing Continental's foreign distribution of crude oil, natural gas, and refined products, with headquarters at 30 Rockefeller Plaza, New York. Starting with The Texas Co. in 1925, Ernst has oil industry experience in Asia, Africa, Europe and South America. During World War II, he was chief, Petroleum Division, Lend Lease Administration and Foreign Economic Administration, Washington, D. C. Since 1946, he has been with California Texas Oil Co., Ltd., New York, first as assistant to the chairman of the board and subsequently as vice president.

John Hawkinson, vice president, treasurer and a director of Central Life Assurance Co. of Des Moines, Iowa, has been elected to the board of directors of Douglas Oil Co. of California. Prior to joining Central Life in 1949, Hawkinson had been with the investment banking firm of Halsey, Stuart & Co., Inc., in Chicago and New York. Born in Walker, Iowa, Hawkinson attended the State University of Iowa where he graduated with a B.A. degree in business administration. During World War II he served as a Lt. Colonel in Army Intelligence in the European Theater.

Hawkinson

K. W. Bartz has been appointed to Humble Oil & Refining Co.'s Research & Development Division, Baytown, Texas. Other new men in the division are **L. R. Harrington, J. R. Hopper, M. S. B. Munson, J. A. Planchard, E. E. Poirot** and **A. T. Watson.** Bartz, Harrington and Watson hold Ph.D. degrees in chemistry; Munson, a Ph.D. degree, and Hopper, Planchard and Poirot, B.S. degrees in chemical engineering.

W. A. Morgan has been promoted to senior research physicist in Humble Oil & Refining Co.'s Research and Development Division, Baytown, Texas. He is engaged in the design and development of electronic equipment for control systems. Morgan holds a B.S. degree in mechanical engineering from University of Michigan.

James H. O'Neal has been appointed senior staff engineer in the General Engineering Department, Whiting, Ind. He has a B.S. degree in mechanical engineering from Purdue University, and started with Standard in 1951.

Dr. George W. Bailey has joined the technical staff of Esso Research Laboratories, Baton Rouge, La. Other new men who have joined Esso are **Dr. Harry Drushel, Preston L. Durill, Dr. William T. House, Dr. Philip W. Pritchett, Dr. Edward L. Steele, Gerrit S. Swart, Glenn A. Pine, Dr. Richard M. McKinley** and **Raymond C. Lohman.**

Dr. James P. Forsman has joined the staff of Esso Research and Engineering Co., Linden, N. J. Other new Esso staff members are **George F. Lewenz, William F. Overberger** and **Leo A. Rapoport.** Dr. Forsman was a research chemist with Jersey Production Research Co. for seven years before joining Esso Research. He received his B.S. degree in chemistry from Princeton University and his Ph.D. degree in organic chemistry from Washington University.

Before coming to Esso Research, Lewenz was with The Texas Co. as a chemist for five years. He received his B.S. and M.S. degrees in chemistry from Western Reserve University.

Overberger was with Goodyear Tire

New handy refractory guide

Here are a few of the technical factors covered...

Abrasive qualities
Acid resistance
Coefficient of expansion
Composition
Compressive strength
Conductivity
Drying shrinkage
Fusion point
Modulus of rupture
Selling properties
Temperature limit

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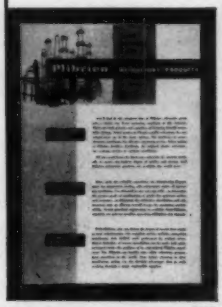

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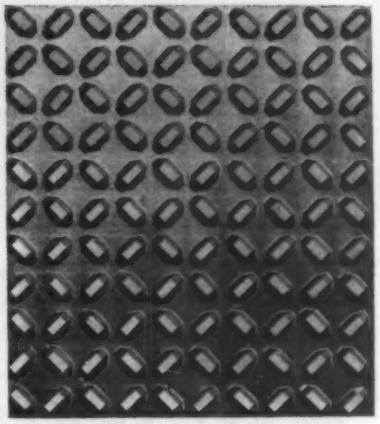

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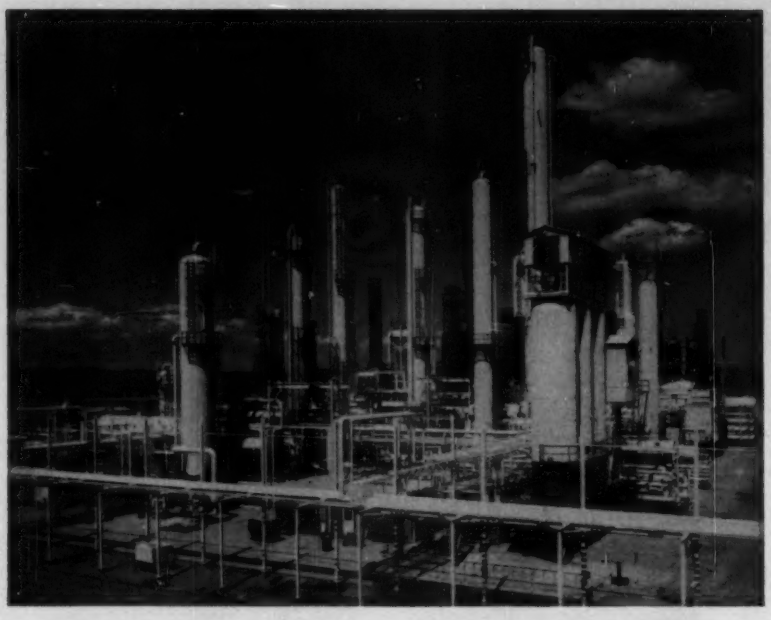

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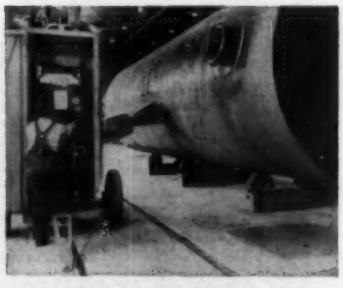

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Men . . .

& Rubber Co. before joining Esso Research. He received his B.S. degree in chemical engineering from Pennsylvania State University

Rapoport also was with the Jersey Production Research for 11 years before joining Esso Research.

J. H. Doores has been elected a vice president of Esso Export Corp., succeeding **P. C. Miller,** who is retiring. Doores, a graduate of Iowa State College with a degree in chemical engineering, joined the Jersey Standard organization in 1944 as operations analysis engineer at the Baton Rouge refinery, Esso Standard Oil Co. He transferred to the Coordination and Petroleum Economics Department of Jersey in 1953, becoming head of the Coordination Division concerned with economic analysis of the company's foreign and domestic affiliates.

Doores

Max Key has been named operations vice president of Dow Chemical International, Ltd., S.A. He was formerly plastics production manager of Dow's Midland, Mich., Division. **A. M. Griswold,** vice president of Dow International, and **E. K. Stilbert,** manager of coatings materials for the Dow Plastics Department, were named product group vice presidents.

Key will direct the process selection, design, engineering, construction and initial operations of all production plants utilizing Dow patents in the geographical areas for which Dow International now has responsibility.

Griswold and Stilbert will be responsible for the future planning of Dow International manufacturing activities in their respective product groups. Griswold will handle the chemical and magnesium group and Stilbert the plastics and textile group.

John E. Brewster has been appointed manager of supply and transportation of Commonwealth Oil Refining Co., Inc. He will locate in Commonwealth's New York office. Prior to this appointment Brewster had been Southern Division manager of Indiana Oil Purchasing Co., Tulsa. He attended Arkansas A&M College and entered the oil industry in 1948 with Root Petroleum Co. Before joining Indiana Oil Purchasing Co. he was with Pan-Am Southern Corp., New Orleans.

Robert S. Boyd, appraisal manager for Stone & Webster Engineering Corp., has been named an assistant vice president of the company. Also named to like posts were **J. Marshall Hamill,** administrative assistant in Boston, and **Wilbur S. Roberts, Jr.,** manager of new business activities, New York. A graduate of Carnegie Institute of Technology, Boyd is a member of AGA, American Society of Ap-

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Men . . .

praisers and the National Society of Professional Engineers. Hamill, a U.S. Naval Academy graduate, joined Stone & Webster in 1946 and has worked on the design of chemical and petrochemical plants in Great Britain and various parts of the U.S. Roberts, who has headed the New Business Division since January 1958, graduated from Union College in Schenectady. During World War II, he was with the War Production Board in Washington. From 1949 through 1953 he was assigned to Great Britain where Stone & Webster was erecting a petroleum refinery.

J. A. Reid has been named director of research for Phillips Petroleum Co. succeeding W. B. Reynolds who has resigned. Reid was formerly director of research for Phillips and had held that position for six years when he was loaned to Astrodyne, Inc., in January, 1958, as executive vice president and general manager. Reid joined Phillips in 1933 after receiving his B.S. degree from the University of Wisconsin and completing 3 years of graduate study at Princeton University. His work with Phillips ranged from basic laboratory research to his responsibilities of directing the company's broad range of research activities. He spent two periods on loan from Phillips in Washington, D.C., on the synthetic rubber program, the last as director of the RFC's office of production for synthetic rubber, tin, and abaca.

G. W. Jack has been named division director in charge of product research and administrative and patent activities, American Oil Co.'s Research and Development Department, Texas City. **H. M. Knight** advanced to group leader in chemicals research, and **H. H. Hammen** of petroleum research was promoted to senior chemist. New men joining the department are **L. E. McMakin, R. H. Brierley,** and **C. A. Chase.**

J. E. Cauley, Jr., has been promoted to senior chemical engineer in the Technical Division at Humble Oil & Refining Co.'s Baytown, Texas, refinery. He is now engaged in the design of facilities to increase production of Butyl rubber. Cauley holds B.S. and M.S. degrees in chemical engineering from The University of Texas.

Dennis C. Shea, assistant employe relations manager of Esso Standard Oil Co., has begun an assignment of about a year in Norway with another affiliate of Standard Oil Co. (New Jersey). During Shea's absence, his position at New York headquarters will be filled by **J. Edwin Hughey,** who has been operations superintendent at the company's Bayonne, N. J., refinery. Shea will serve as employe relations advisor to the management of A/S Esso-Raffineriet. He joined Esso's Employe Relations Department in New York in 1952 as assistant manager for manufacturing.

E. F. Grieb has been appointed manager of American Cyanamid Co.'s Fortier acrylonitrile plant, New Orleans, succeeding **C. F. Bonnet,** who has been named associate regional director-Europe of Cyanamid International. **T. D. Smith** has been named assistant plant manager and **J. J. Fitzgerald** has been appointed manager of operations.

Grieb

Grieb has been with Cyanamid since 1935 when he joined the company as a chemist at its Bound Brook, N. J., plant. He became manager of operations for the Fortier plant in May, 1956, and was named assistant plant manager early in 1958.

Smith was with Jones & Laughlin Steel Co. and served with the U.S. Army prior to joining Cyanamid in 1946. In January, 1956, he was named production manager for the company's Marietta, Ohio, and Willow Island, W. Va., plants. Early last year he was appointed manager of operations for the Fortier plant. He is a graduate of Muskingum College in New Concord, Ohio.

Fitzgerald joined Cyanamid in 1949. He was with the company's Plastics & Resins Division until 1953 when he transferred to the Fortier plant. Since

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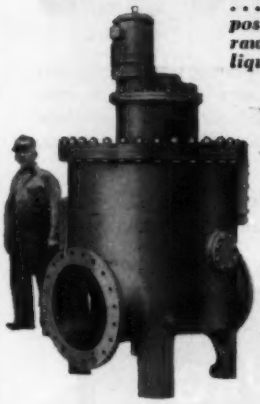

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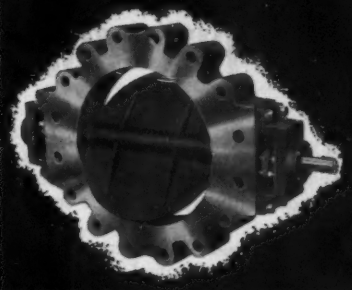

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DU PONT *Petroleum Chemicals* NEWS

Number 98 in a Series of Bulletins for the Petroleum Industry

SEPTEMBER-OCTOBER 1959

How to use winter weather and RP-2 to increase brand loyalty for your gasolines

New TEL Manager

JOHN R. SABINA is our new manager of the tetraethyl lead and planning section of Du Pont's Petroleum Chemicals Division. He replaces T. Baldwin Prickett, who retired March 31 after 33 years in the petroleum industry.

Mr. Sabina joined the Du Pont Company in 1937, heading a new group in the Organic Chemicals Department. In 1944, he became manager of the petroleum chemicals section and two years later became technical manager of the newly formed Petroleum Chemicals Division.

Has Published Many Technical Articles

Mr. Sabina holds a B.S. in Electrical Engineering from the University of Pennsylvania and was associated with the Atlantic Refining Company before joining Du Pont. He is well known for his numerous technical articles in the petroleum field and his activities in technical societies.

PERISH THE THOUGHT from all *your* customers' minds . . . by including Du Pont RP-2 in your fall and winter gasoline blends. Du Pont RP-2 prevents carburetor icing, the most common cause of stall annoyance that can frustrate motorists into switching gasoline brands. RP-2 also prevents rust, acts as a carburetor detergent and supplies valuable phosphorus credit.

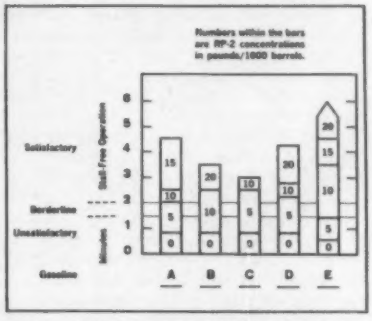
When the frost is on the ground and cold, wet winds once more fill the air, you'll have a better chance than ever to build up loyalty to your brand of gasoline.

It's when his car stalls that a motorist starts *shopping* for his gasoline and considers seriously which brand gives him the best performance.

We can help you cash in on this with Du Pont RP-2, an additive that gives three-way protection to your customers' cars and a "phosphorus bonus" to you.

Prevents stalling due to carburetor icing. RP-2 keeps throttle plates and throats of carburetors from being wetted by water droplets. Sufficient RP-2 in *your* gasoline will keep customers' carburetors from icing up during adverse weather. The chart on this page shows just how this affects anti-stalling properties.

Keeps carburetors clean RP-2 coats throttle plate, throat, and walls of carburetor, adds a detergent action which prevents foreign matter from building up into a choking scale. This action keeps new carburetors clean, cleans old carburetors previously used with gasolines unprotected by RP-2.



Controls rust RP-2 forms a barrier between metal and moisture, blocks rust formation before it can start . . . prevents rust in the fuel system and during storage, too.

ADVERTISEMENT—Prepared for the Petroleum Chemicals Division of E. I. du Pont de Nemours & Company (Inc.)

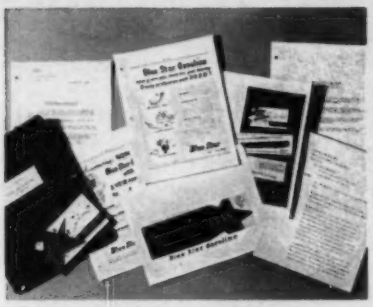
OVER

DUPONT *Petroleum Chemicals* NEWS

CONTINUED

Phosphorus credit You can take a phosphorus credit when you use RP-2. At 15 pounds per 1000 barrels, RP-2 adds about 0.03 theory of phosphorus to premium grade gasoline.

How to get started for next winter First, you'll want the complete technical story on RP-2, contained in a new bulletin. You can get a copy by calling your Du Pont representative or writing us direct.



You can follow this up with this complete merchandising and advertising kit, based on proven methods for getting the optimum attention from your market when you use RP-2 additive.

Have you heard about our linear programming service?

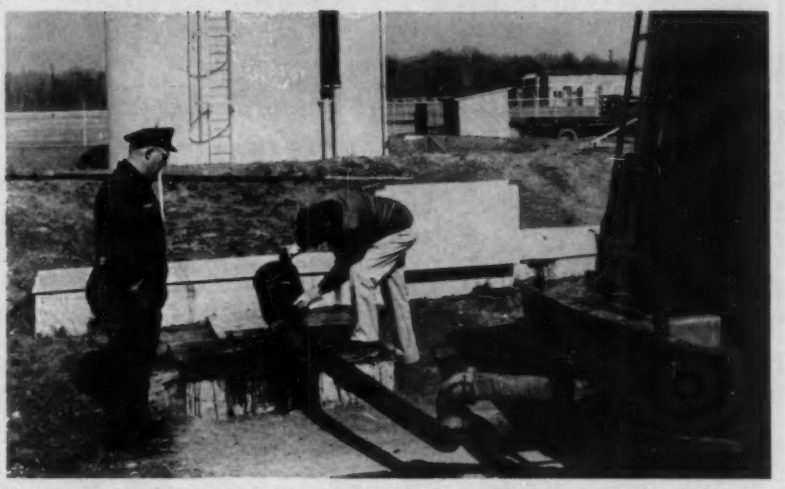
In case you missed our offer a few months ago, we take this chance to reiterate the fact that we have set up a linear programming service in our Petroleum Chemicals Division.

This service can help you organize the vital variables of processing and blending in such a way that modern calculation methods can be applied to get an integrated analysis of all gasoline manufacturing operations.

A study covers such factors as: the value of each gasoline component . . . optimum reformer severity . . . the volume of components which should be purchased or sold . . . the product quality shortage or give-away on all inspections related to specifications . . . the loss sustained by diverting components to other grades of gasoline or products through choice or necessity . . . and economical use of tetraethyl lead.

For more information on this service, see your Du Pont representative or write Du Pont, Petroleum Chemicals Division, Wilmington 98, Delaware.

FOA-2 gives fast answers to sludging problems from heavy fuels



At a large industrial chemical laboratory, Du Pont FOA-2 was added to a sludge-ridden tank during fuel delivery. Tank was successfully de-sludged with only $20 worth of FOA-2, with no down-time. This eliminated need for $800 mechanical cleaning.

A chemical manufacturing plant found it could save $600 per cleaning by using Du Pont FOA-2 in an eighteen-U-tube oil heat exchanger which previously had to be dismantled twice a year for cleaning.

At a large laboratory, operators no longer have to clean the burner tip in their boiler every five days . . . in fact, they have not cleaned it at all since they started adding FOA-2 to their fuel, months ago.

A large office building had to clean a burner nozzle every day, including weekends. FOA-2 makes it possible for the same burner to run for four days without a cleaning.

A chemical plant had a serious sludge problem in its preheater when tubes became plugged with deposits so hard they couldn't be cleaned at all. Since adding FOA-2 to their fuel, this problem has ceased and over-all cleaning time has been cut by four-fifths.

These are just five of many recent success stories for FOA-2.

If you're having a sludge problem from the use of heavy fuels, such experience shows that you can count on eliminating or at least minimizing the problem with the help of FOA-2.

If you'd like to know more, contact the Du Pont Petroleum Chemicals Division representative nearest you, or write us direct for a bulletin.

SALES OFFICES

Chicago 3—8 So. Michigan Ave. . . . . RAndolph 6-8630
Cleveland 15—101 Prospect Ave. . . . . MAin 1-3422
Houston 2—705 Bank of Commerce Bldg. . . . CApitol 5-1151
Los Angeles 17—612 So. Flower St. . . . . MAdison 4-1354
New York 20—45 Rockefeller Plaza. . . . COlumbus 5-2342
Philadelphia 2—3 Penn Center Plaza . . . . . LOcust 8-3531
Pittsburgh 22—1 Gateway Center. . . . . ATlantic 1-2933
San Francisco 4—111 Sutter St. . . . . EXbrook 2-1934
Seattle 3—4003 Aurora Ave. . . . . MElrose 2-6977
Tulsa 1—1811 So. Baltimore Ave. . . . . LUther 5-5578
In Canada—Du Pont of Canada Limited, Petroleum Chemicals, 85 Eglinton Ave. East,
Toronto 12—Ontario. . . . . HUdson 1-6461
OTHER COUNTRIES: Petroleum Chemicals Division, Export Sales, Wilmington 98, Delaware, PRospect 4-2962.

DU PONT
REG. U. S. PAT. OFF.

Better Things for Better Living
. . . through Chemistry

Du Pont Tetraethyl Lead and other Petroleum Additives

OVER

ADVERTISEMENT—Prepared for the Petroleum Chemicals Division of E. I. du Pont de Nemours & Company (Inc.)

A-11520

Printed in U.S.A.

Men . . .

that time he has held several production positions at the plant, most recently serving as general superintendent of production.

James A. Ransford has been named Washington, D.C., representative for Tidewater Oil Co. An oilman for 35 years, he succeeds **L. W. Parsons,** Tidewater's Washington representative since 1942, who has retired. Ransford began his career at Tidewater's Avon, Calif., refinery laboratory in 1927, after attending the University of California. Before and during World War II he handled the company's sales training and specialty products sales, and in 1946 was appointed sales personnel supervisor.

Ransford was named assistant manager of wholesale sales in 1947, and in 1950 acted as Tidewater's representative in overseas operations with the Mitsubishi Oil Company, Japan. Since 1950 Ransford has handled Tidewater marketing assignments on the West Coast, including sales training, wholesale sales and export sales.

Dr. H. D. Medley has been appointed director, new chemical development, for Celanese Chemical Co.'s Product Department, New York. Since 1955 Dr. Medley has been head of the Basic Process Research Section of the company's Clarkwood, Texas, research laboratories. He joined Celanese in 1952 as a research chemist and was made a group leader the following year.

Dr. Medley graduated from Southwestern University with a B.S. degree in chemistry in 1948 and obtained his Ph.D. degree in organic chemistry from The University of Texas in 1952. He is a member of Sigma Xi, Phi Lambda Upsilon, Alpha Chi, American Men of Science, New York Academy of Science and ACS, having been chairman elect during 1958. Dr. Medley succeeds **Dr. H. L. Pilat** who has joined Celanese Plastics Co.

Benjamin F. Steely has been named senior staff engineer in Standard Oil Co. (Indiana), General Engineering Department, Whiting, Ind. He received his B.S. degree in civil engineering from the University of Wisconsin in 1949, and started with Standard in 1952.

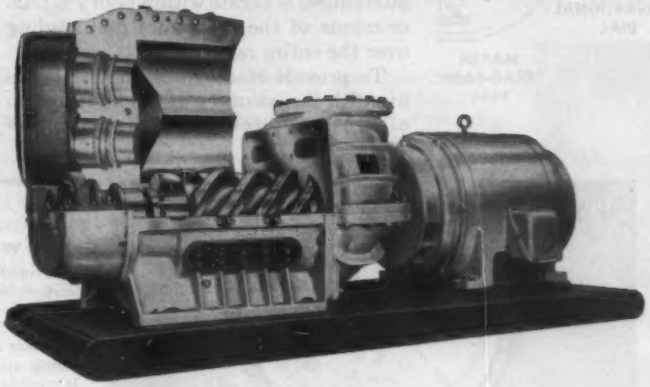
Robert V. Peaslee has been elected vice president of The Ralph M. Parsons Co., Los Angeles. Formerly vice president of C. F. Braun & Co., he will be located at the New York office of Parsons.

Now turn to Page 421 and read "Suppliers Notes" to keep informed about those who supply and service the industry.

You'll find this is

the only rotary compressor

with all these features!



Fairbanks-Morse Positive Displacement Axial-Flow Rotary Compressors are available in standard models in single-stage units, with capacities from 800 to 12,500 cfm. at compression ratios from 1.6:1 to 5.0:1—or in two-stage units with capacities from 2,000 to 12,500 cfm. at compression ratios above 5.0:1—and for booster service at maximum working pressures up to 250 psig.

- **High efficiency and stability** that rivals reciprocating machines.
- **Low weight and small space** requirement that cuts costs for installation, foundation and building.
- **Oil-free output**—no metal-to-metal contact of impellers or casing, no lubrication of parts contacting gas, air or vapor.
- **Mechanical simplicity**—no valves, no pistons or reciprocating parts to wear or replace.
- **Adaptability to any power source** permits choice of induction or synchronous motor, diesel engine, gas or steam turbine as prime mover.
- **Smooth, steady operation**—impeller speed and design produce even delivery of flow with minimum pulsation or vibration.

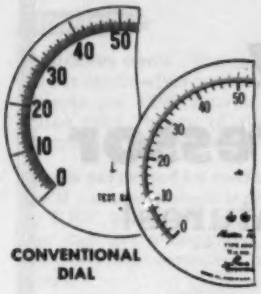
For complete information contact your nearby Fairbanks-Morse Branch, or write Fairbanks, Morse & Co., 600 So. Michigan Ave., Chicago 5, Ill. Ask for new Bulletin ACO 100.2.

FAIRBANKS-MORSE

a name worth remembering when you want the BEST

COMPRESSORS • PUMPS • SCALES • DIESEL, DUAL FUEL AND GAS ENGINES
LOCOMOTIVES • ELECTRIC MOTORS • GENERATORS • MAGNETOS • HOME WATER SYSTEMS

Presenting New MARSH "*Master-Test*" SERIES
of extremely accurate test gauges

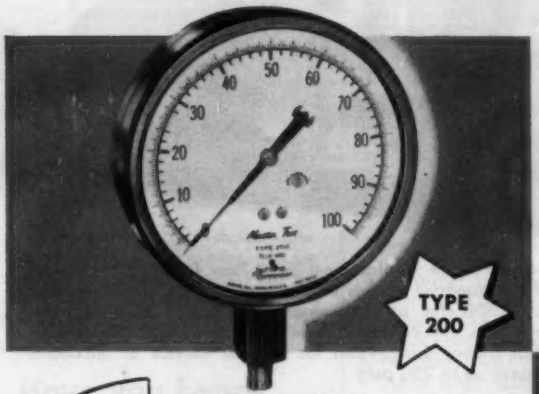


Crowning achievement in instrument making... this superb series of test gauges developed to meet today's exacting requirements of instrument men throughout industry. Accuracy and dependability beyond compare...each gauge individually dead-weight tested (think what that means!)...each gauge guaranteed accurate within ¼ of 1% plus or minus of the maximum dial reading over the entire range.

To provide reading accuracy in keeping with the accuracy of the instrument, all "Master-test" gauges have the simplified "Read-easy" dial (patent pending) illustrated opposite—a dial that can be read with the accuracy of a caliper, yet with the ease of a clock.

To further increase accuracy, three advanced means of reading have been developed as described below: the "twin-tip" pointer; the mirror path; the non-parallax dial.

"Master-test" gauges are available in sizes 4½", 6", 8"...in all standard ranges from 0-15 to 0-30,000 psi...in vacuum and compound types...in a full range of case patterns. Ask for 20 page bulletin.



← with "Twin-tip" pointer

The most common error in reading pressure occurs when the observer reads from an angle rather than "dead on". This Marsh "Twin-tip" pointer enables the operator to know when he is dead on by lining up the two tips so that only one is visible. The twin-point arrangement is similar to the sights on a rifle.

with mirror dial →

Another method of insuring accurate "dead on" reading. Knife edge pointer is reflected by the mirror path. When reflection is not seen, reading is dead on and true. The ease and accuracy with which the mirror dial may be read cannot be duplicated by any other mirror type dial. It is the combining of the mirror path with the exclusive Marsh "Read-easy" dial that makes this faster, error-free reading possible.

← with "Non-parallax" dial

This Marsh development eliminates mistakes in dial reading even if read at an angle. To accomplish it Marsh engineers designed a clear Plexiglas insert placed, as shown, over the fine graduations so that they appear to be at the same level as the pointer regardless of the viewing angle. The "Non-parallax" dial provides the easiest and most accurate dial reading available.

Ask for this 20 Page Bulletin

MARSH

THE STANDARD OF ACCURACY

MARSH INSTRUMENT COMPANY, Dept R, Skokie, Ill.

Division of Colorado Oil and Gas Corporation • **Marsh Instrument & Valve Co., (Canada) Ltd. 8307 103rd St., Edmonton, Alberta, Houston Branch Plant, 1121 Rothwell St., Sect. 15, Houston, Texas**

Suppliers Notes...

Young

H. Ben Young, director of engineering and research at W-K-M Division of ACF Industries since 1956, has been elected a staff vice president of ACF Industries, Inc. His new responsibilities in engineering and research will encompass the work of ACF Industries' seven operating divisions, including W-K-M. Before Young joined W-K-M he was with Mission Manufacturing Co. as chief engineer and, subsequently, director of overseas projects. He is a member of ASME and is a registered professional engineer.

William Kneen has been named chief project engineer, Analytical & Control Instrument Division, Consolidated Electrodynamics Corp. He joined CEC in January, 1954, as a training engineer, and became an application engineer in November, 1954; supervisor of digital instrumentation group in 1956; and an engineering group supervisor with the Analytical & Control Instrument Division in 1958. Previously, he was an instrumentation and analysis engineer with Pullman Standard Car Manufacturing Co.

Kneen

Holman

Herbert A. Holman has been named Chicago area district engineer, sales, for Blaw-Knox Co., Chemical Plants Division, Pittsburgh. He will headquarter in the company's Chicago sales office. Holman joined Blaw-Knox in 1952, soon after graduation from Purdue University with a B.S. degree in civil engineering. He has since been responsible, as construction superintendent, for many projects in the petroleum, petrochemical, plastics, chemical, and fertilizer fields.

David C. McNeely has been named manager of the Helipot Division of Beckman Instruments, Inc., Fullerton, Calif. He had been acting manager of the division since April, 1958. McNeely joined Beckman as Helipot sales manager in 1953. Earlier he was sales manager for the Philadelphia Gear Works and manager of distributor sales for Morse Chain Co., Detroit. He graduated in mechanical engineering from Purdue University.

McNeely

Holladay

Maurice E. Holladay has been appointed a vice president of Chicksan Co., Brea, Calif., and general manager of the firm's newly acquired Hamer Valves Division. He had been vice president and co-manager, with L. S. Hamer, of Hamer Valves, Inc., Long Beach, Calif., prior to the recent purchase by Chiksan of the Hamer firm.

Holladay joined Hamer's Engineering Department in 1936. He is a registered mechanical engineer.

Harold W. Wahl has been named manager of American Meter Co.'s Southwest Division. Since 1950, he has been manager of the Southern Division of Westcott & Greis, Inc., an American Meter subsidiary recently incorporated into the company's Southwest Division. He makes his headquarters in Dallas. With American Meter since 1919, Wahl is a director of the Southern Gas Association and member of AGA, Independent Natural Gas Association and the Mid-Continent Oil and Gas Association.

Wahl

Kross

George W. Kross, Jr., has been named assistant manager of tubing operations at the Tubular Products division, Beaver Falls, Pa., plant of The Babcock & Wilcox Co. He started with the company at its Beaver Falls plant in 1947 as a student engineer. In 1952 he became assistant to the plant superintendent at the Keystone St., Alliance, Ohio plant, and in 1953 he was made assistant superintendent. In 1955 he became plant superintendent.

Harold O. Proske, director of sales aids and training, has been named branch manager, Shreveport office of Rockwell Manufacturing Co.'s Meter and Valve Division. He joined Rockwell in 1938 as a sales engineer in the Kansas City District, was transferred to Pittsburgh headquarters in 1951 as service manager, named assistant sales manager-Gas Products in 1952, and promoted to national representative of the Gas Products Division in 1953. Proske assumed his most recent position in 1954.

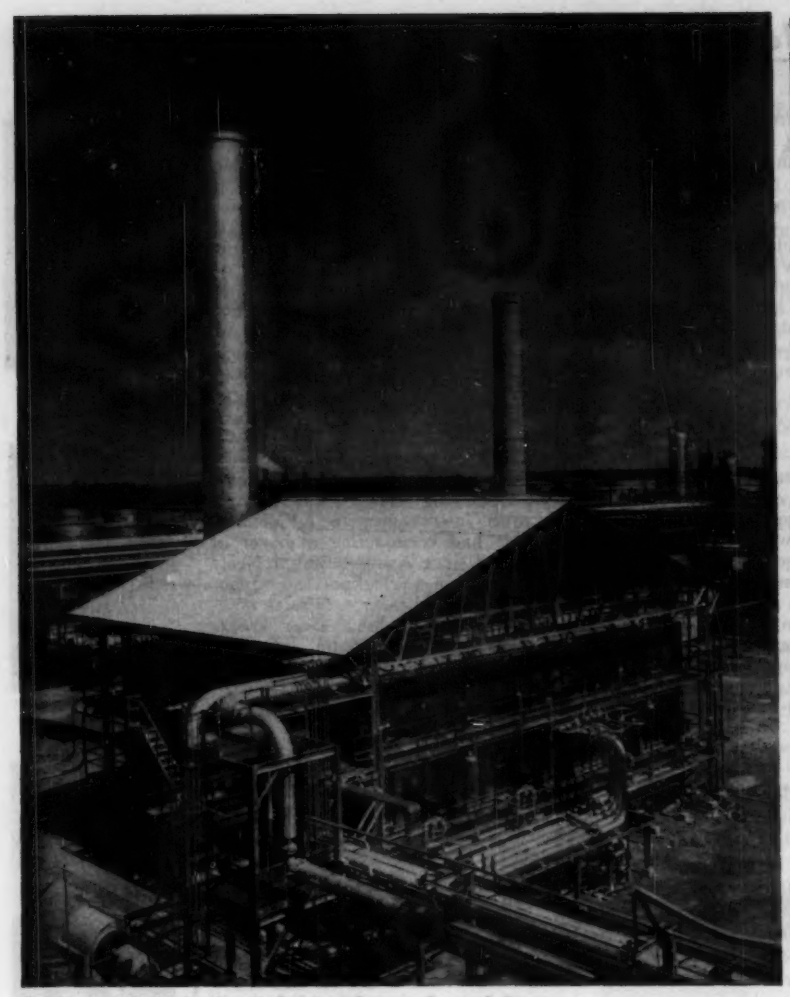
Proske

Kline

John S. Kline has been appointed general manager and chief executive of The Carpenter Steel Co.'s Alloy Tube Division, Union, N. J., to succeed P. L. Coddington. Kline has been assistant general manager of the Alloy Tube Division since October 1958. Before that he was divisional controller of both the Alloy Tube Division and Carpenter's Webb Wire Division in New Brunswick, N. J., for six years. He joined Carpenter as an auditor at Reading, Pa.

Hugh Mullen has been appointed vice president in charge of operations for Buell Engineering Co., Inc. He was formerly director of purchasing and administrative assistant to the president. Mullen has spent his entire business career with Buell Engineering, having joined the company's research and development staff at New York headquarters in 1946. He subsequently transferred to the Purchasing Department, and was

Mullen



Portable crude heater for Magnolia Petroleum Company, Beaumont, Texas.

Ultraformer heater for American Oil Co. at El Dorado, Arkansas.

Platformer and desulphurizer heaters for Shell Oil Co. at Deer Park, Houston, Texas.

HIGHER EFFICIENCY, LUMMUS OIL HEATERS

Lummus designs horizontal and vertical-tube oil heaters to any size, for any process—anywhere in the world

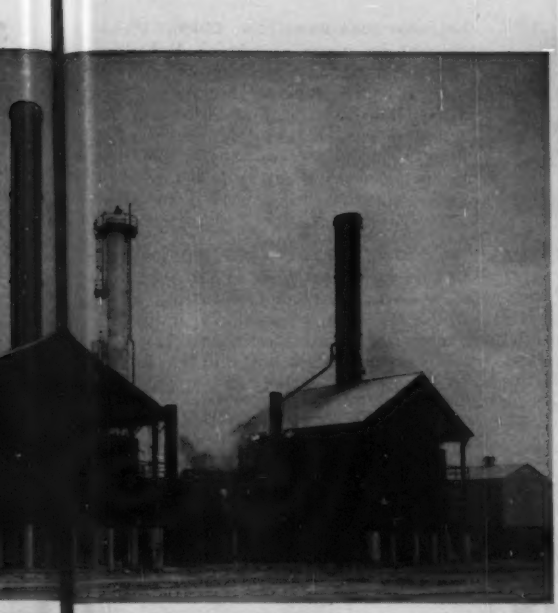
Major refiners confidently turn to Lummus on their important and difficult oil heater jobs.

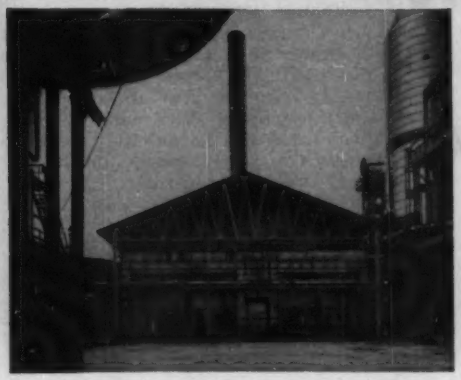
In the last 25 years, the combined capacity of all Lummus oil heaters built has exceeded that of any other company in the world. The reasons: greater durability, more efficient operation, an absolute minimum of days lost to downtime.

Major refiners maintain large engineering and economics staffs who can evaluate the performance of important heating equipment. They buy more Lummus oil heaters because they *know* through statistical comparison that Lummus gives them *more heater per dollar.*

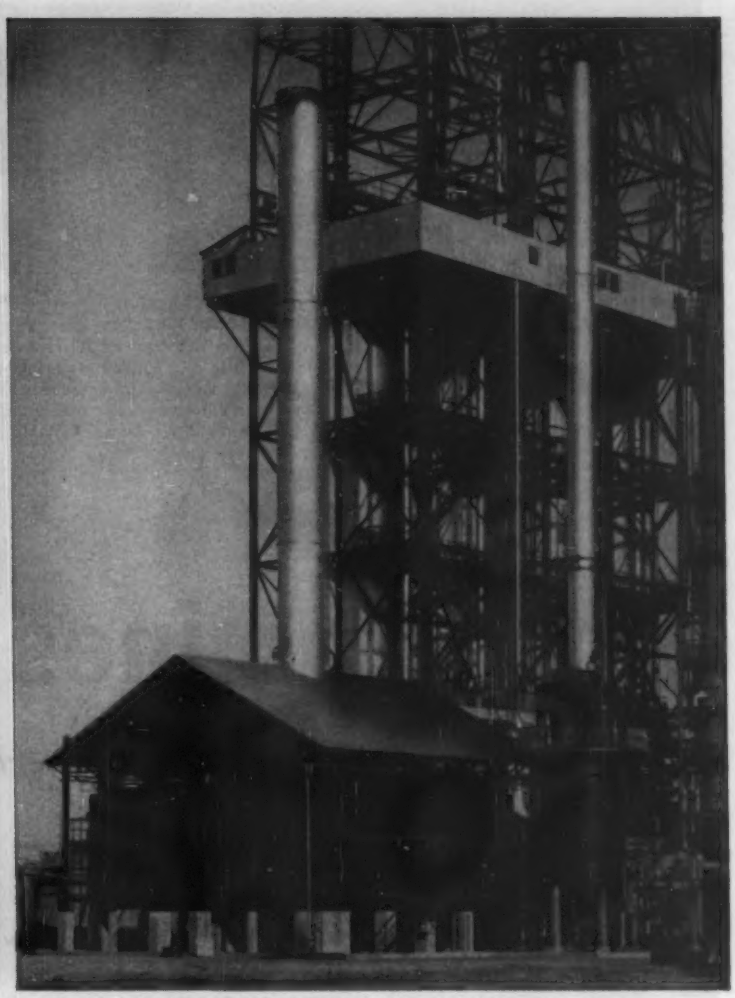
Lummus offers over a quarter of a century of oil heater experience for petroleum refineries, chemical and petrochemical plants. The highly trained engineering staff of the Oil Heater Division is ready in the Lummus New York office to give each job the full benefit of its accumulated know-how in this field.

Lummus oil heaters, of both special and standard design, range from 100,000 to 300,000,000 Btu per hour. As illustrated above, neither size, type nor location of the unit presents a problem to Lummus. Because Lummus offers *every* type of oil heater, you can be sure that we will recommend the *right*





Crude heater for Socony Mobil at Paulsboro, N. J.



Delayed coker heater for the American Oil Co. at Yorktown, Virginia.

MINIMUM DOWNTIME MAKE PREFERRED AMONG MAJOR REFINERS

unit for your needs. Complete Lummus facilities are available world-wide through any of the five international Lummus companies. Equipment is designed in New York, procurement is made through the nearest Lummus international office, and the cost of the job is payable in the currency of the country in which the procurement is handled!

Consult with Lummus on your next oil heater – large or small.

LUMMUS

THE LUMMUS COMPANY, OIL HEATER DIVISION
385 MADISON AVENUE, NEW YORK 17, N. Y.

WASHINGTON, D. C. • HOUSTON • MONTREAL • MARACAIBO • LONDON • PARIS • THE HAGUE

For more data on advertised products, use Readers' Service Cards, last page.

Suppliers . . .

named director of purchasing and administrative assistant to the president in 1957.

JONES & LAUGHLIN SUPPLY DIVISION has named **S. M. Dippel** salesman, Victoria, Texas. He has a B.B.A. degree from Southern Methodist University.

EMERY INDUSTRIES, INC. is planning a $6-million plant expansion at Cincinnati. New construction will increase several fold the capacity for production of azelaic and pelargonic acids from oleic acid by ozone oxidation. The present plant, completed five years ago, is said to be the world's only installation for commercial oxidation by ozonolysis.

Mayer

Milton

SHAND AND JURS CO. has named **Rex W. Milton** manager of its Houston sales office. **Bill W. Mayer** will become assistant to the Houston manager. He had previously been in sales and engineering at the company's Berkeley, Calif., headquarters.

need ethanolamines?

Get immediate delivery from local stocks

In the Southwest, call:

Houston, Texas
RANGER CHEMICAL COMPANY

Odessa, Texas
WESTERN CHEMICAL COMPANY

Borger, Texas
WESTERN CHEMICAL COMPANY

Farmington, N. Mex.
WESTERN CHEMICAL COMPANY

Top quality Mathieson ethanolamines are also available from distributors in other areas and in tank car, tank truck and drum shipments from the Brandenburg, Kentucky, plant. For data sheets, samples, or further information, see your Olin Mathieson representative or write today.

MATHIESON

OLIN MATHIESON
CHEMICAL CORPORATION
Chemicals Division · 745 Fifth Ave., N. Y. 22

6505

BALDWIN-LIMA-HAMILTON CORP., Philadelphia, has elected **Frederick A. Fielder** vice president and general manager of the Loewy-Hydropress Division, New York. General sales manager and assistant general manager of the division since 1955, Fielder succeeds the late **Erwin Loewy** who founded the companies that have become the Leowy-Hydropress Division.

THE COOPER-BESSEMER CORP. has assigned **Donald E. Dixon** to its Houston branch office. A graduate of Oklahoma State University with a degree in Industrial Engineering, Dixon had been located at the company's sales office in Tulsa and at the Mount Vernon, Ohio, plant.

BROWN INSTRUMENTS DIVISION, Minneapolis-Honeywell Regulator Co., has named **William F. Newbold** director of research. He graduated from Princeton University and joined Brown Instruments in 1948, serving successively as a research engineer, assistant to the director of research, section head, and assistant research director.

FAIRBANKS, MORSE & CO. plans to establish a central research and development laboratory in a modern 20,000 square foot building at the company's works in Beloit, Wis. The new lab will operate independently of all manufacturing activities and will be devoted entirely to research and development for the corporation's product divisions.

AMERICAN CYANAMID CO.'s Industrial Chemicals Division has named **Richard G. Keppler** sales manager of refinery chemicals. He joined Cyanamid in 1953 as senior technical representative, Refinery Chemicals Department, and has since had sales and administrative jobs in Houston and Chicago.

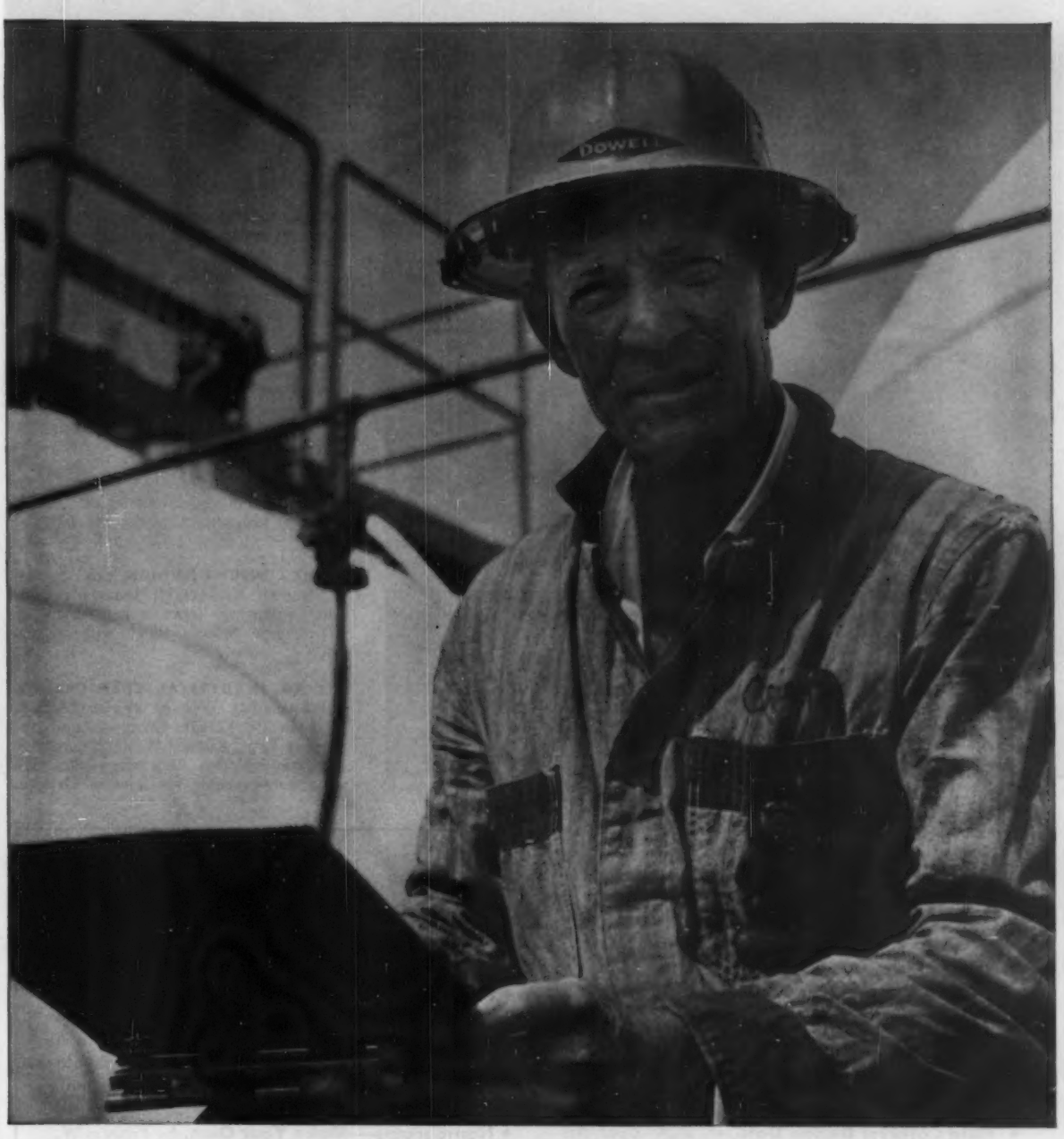
THOMPSON-RAMO-WOOLDRIDGE PRODUCTS CO. has named **Ray J. Standish** central regional sales manager, Chicago, and will be responsible for all sales activities in the central United States. Prior to joining TRW Products in 1958, Standish held engineering positions with Thompson Products, Inc., Cleveland, including that of chief engineer, Replacement Division.

JEFFERSON CHEMICAL CO., INC., has named **Douglas M. Stewart** to its sales staff. He will headquarter in the Cleveland Regional Sales Office. Holder of a B.S. degree in chemical engineering from Purdue University and M.S. degree in industrial management, he recently completed military service.

WISCONSIN PROTECTIVE COATING CORP. has expanded the territory of its direct factory representative, N. A. D'Arcy Co., 7535 Marbrisa St., Huntington Park, Calif. The new area will include two Southeastern counties of Nevada and the Southeast counties of Utah.

AMERICAN CYANAMID CO.'s Organic Chemicals Division has named **Martin B. Friedman** manager of the Advertising and Promotion Department. With Cyanamid since 1954, when he joined the company's Textile Chemicals Depart-

For more data on advertised products, use Readers' Service Cards, last page.



This Man Can Mean Extra Profit For You

This is a Dowell Service Engineer. He is an expert in the use of chemical solvents to remove scale and sludge from your process systems, boilers, tanks and piping.

Using the exclusive Dowell methods of chemical cleaning, this engineer can free up the profits that these deposits cut from your operating ledger.

More than 15 years experience in all industries—for example, oil refining, chemical, steel, public utilities and paper—give Dowell engineers full knowledge of the problems of cleaning plant equipment.

Add to this experience the benefits you get in special equipment, chemicals, research and trained people.

Put this ability and experience to work for you. Let the Dowell man engineer a profitable chemical cleaning program for you. Dowell—the largest, the oldest, the most experienced chemical cleaning service—Tulsa 1, Oklahoma; and 165 stations and offices in major industrial centers.

Chemical cleaning service for all industry

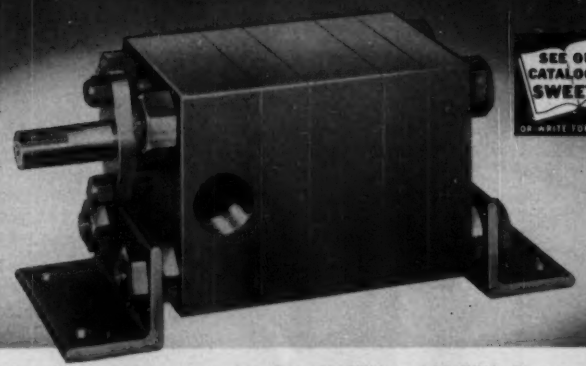
DOWELL

DIVISION OF THE DOW CHEMICAL COMPANY

For more data on advertised products, use Readers' Service Cards, last page.

NORTHERN NITRALLOY PUMPS

Lube oil, seal oil and fuel oil pumps for compressors and engines



Complete range in pump sizes from ¼ GPM to 146 GPM. Pressures to 2000 PSI. Proven in thousands of installations and backed by 50 years of engineering and production experience, Northern Steel Block Nitralloy Rotary Gear Pumps are unexcelled for precision manufacture, accurate assembly and dependable, long life operation. Write for free catalog and engineering data.

NORTHERN ORDNANCE, INCORPORATED
Subsidiary
NORTHERN PUMP COMPANY
MINNEAPOLIS 21, MINN.

Suppliers . . .

ment, he was named advertising and sales promotion manager for the department in 1957, and in 1958 became assistant advertising manager for the Organic Chemicals Division.

THE BABCOCK & WILCOX TUBULAR PRODUCTS DIVISION has named **Thomas W. Wright** assistant manager, New York District sales office. A sales representative in the New York District since 1949, Wright began with B&W in 1946 and worked as a contact metallurgist at the Tubular Products Division's main plant.

ARMSTRONG CORK CO.'s Industrial Division has named **William M. Martin** assistant manager, gasket and packing sales. A graduate of Bucknell University, he served five years in the Cincinnati office as a salesman before being assigned to the general office, Lancaster, Pa., as a technical assistant in gasket and packing sales.

BENDIX COMPUTER DIVISION, Los Angeles, has named **Herbert H. Jones** programming instructor. Jones is a graduate of Jacksonville State College with a B.S. degree.

ARMOUR INDUSTRIAL CHEMICAL CO. has opened a Western regional sales office in Portland, Oregon, and appointed **E. L. Rhoads** Western manager, aliphatic nitrogen derivatives sales. He will be responsible for sales in Oregon,

Popular Petroleum Refiner reprints available . . .

These reprints of PETROLEUM REFINER articles have enjoyed an excellent demand from men in the oil, gas and petrochemicals processing industry. They are available at $1.00 each.

• **Fluid Catalyst Design Data,** by F. A. Zenz: An expert orientation and appraisal of recent development of fundamental studies in fluidization.

• **Perforated Trays,** by Chen-Jung Huang and John R. Hodson: Reliable information for design of perforated trays including handy work sheets to carry out your calculations.

• **1958 Process Handbook:** Contains charts and detailed description of more than 90 important commercially-used refining processes. Plus a Special Report on Alkylation by R. E. Payne . . . and From Flow Sheet to Cost Estimate by W. E. Hand.

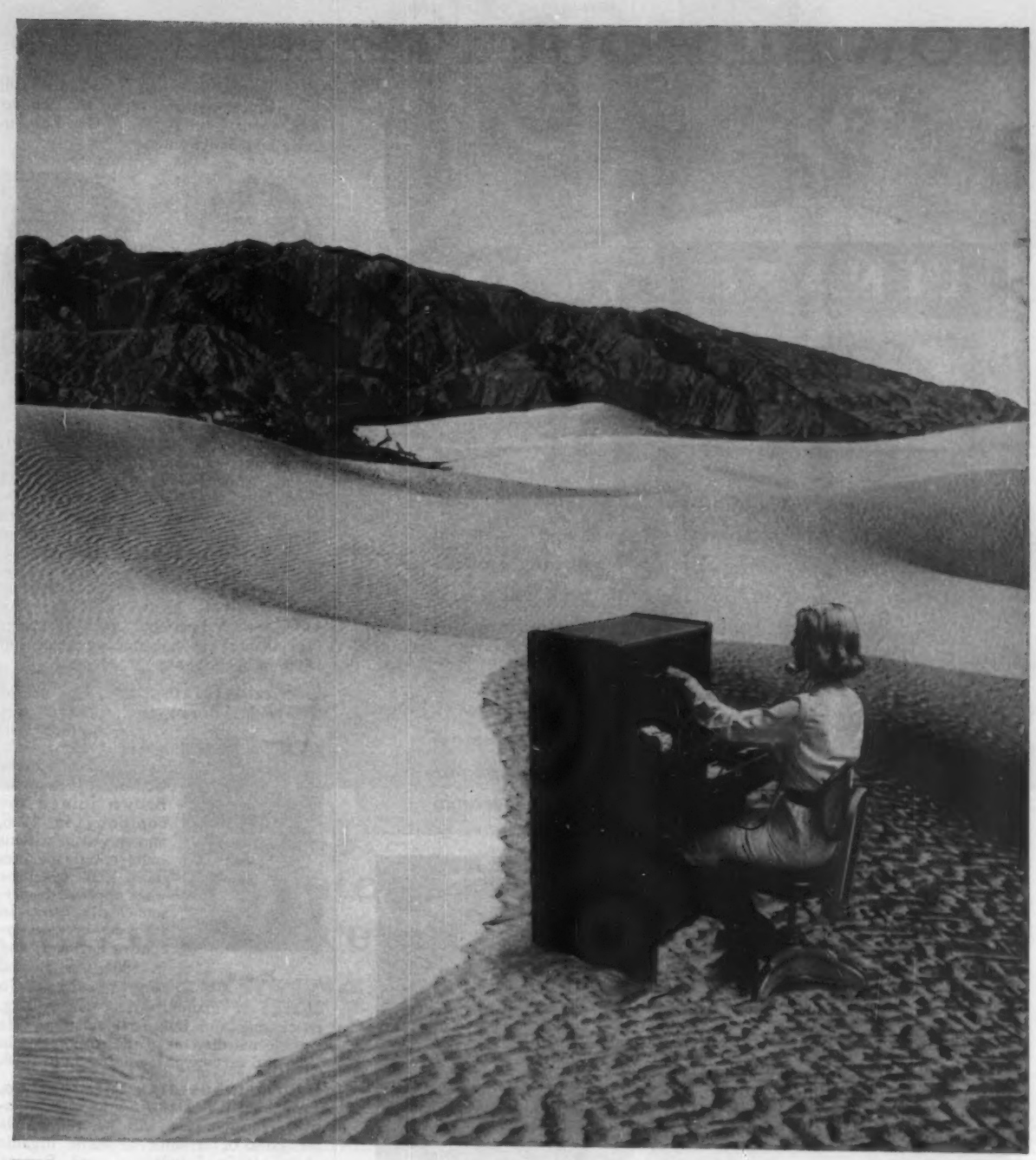
• **Foundation Design for Stacks and Towers,** by V. O. Marshall: Long the standard reference in engineering offices throughout the world, this is a reprint of an article that every design man should keep within easy reach as an effective working tool.

• **Nomograms—Make Your Own,** by Francis W. Winn: Shows you how to prepare various types of scales, how to lay out the nomograms, how to prepare different types of nomograms, how to handle experimental data directly.

• **Six Steps To Better Drafting Practices,** by Frank Evans: Shows you practical ways to step up your design drafting efficiency and cut costs.

Send Cash with Order. Address:

REPRINTS, PETROLEUM REFINER
Box 2608, Houston 1, Texas



This oilwoman waits for a telephone ring that can bring the desert to life.

She's part of the huge oil communications network, proud to be in an industry that is helping the desert to bloom. Example: the Four Corners area, where Utah, Arizona, Colorado and New Mexico meet. Here, wastelands are pulsing with new life and industrial vigor—because of oil. The next time you hear somebody speak out against oil—tell him you're an oilman and glad of it. And tell him why.

SHELL OIL COMPANY

LOW SILHOUETTE

LENAPE

STUDDING OUTLETS

Lenape curved studding outlets or pads are compact in shape and provide inherent reinforcement of the vessel opening. Their low silhouette offers design as well as cost appeal, plus ease and economy of attachment. Use of a supplemental reinforcing ring is completely eliminated.

Important applications include interdeck access openings on small diameter towers or columns, boiler mountings, LPG tanks, clean-out or observation ports and similar uses in close-clearance locations.

Available in standard ID sizes from 1½" to 24" for ASA rated pressure service from 150 lbs. to 2500 lbs.

For detailed specifications, see pages 36-39 of Lenape Catalog 10-53, available upon request.

Compare the low silhouette of Lenape studding outlets with conventional long welding necks on this solvent trap.

See our standard line of pressure vessel connections on pages 1128-1129 in the 1958 Chemical Engineering Catalog.

LENAPE PRESSURE VESSEL CONNECTIONS

LENAPE HYDRAULIC PRESSING & FORGING CO.
DEPT. 106 WEST CHESTER, PA.
RED MAN PRODUCTS

Suppliers . . .

Washington, Idaho and Nevada, and will be technical coordinator for the Armour sales agent, Paul W. Wood Co., Los Angeles and San Francisco.

Link

Dauenhauer

THE OHIO INJECTOR CO. has divided its field sales organization into two regional operations. **Carl G. Link** has been named Eastern regional sales manager responsible for all operations for the Eastern United States. His offices will be in New York. **R. F. Dauenhauer** will be Western regional sales manager, Chicago. Link was previously with New York Belting and Packing Co., a U. S. Rubber Co. subsidiary, as national sales manager. Dauenhauer was sales manager, Central Division, Chicago.

WAGNER ELECTRIC CORP. has named **George W. Brown** president and chief executive officer and president of its subsidiary, Wagner Brake Co., Ltd., Toronto. Brown joined the company in 1926, and served in various engineering capacities until 1937 when he was appointed personnel director. In 1952 he became executive engineer, and in 1954 was elected vice president in charge of manufacturing, engineering, purchasing and industrial relations. He was elected director of the corporation in 1956 and executive vice president in 1958.

Brown

ARMOUR INDUSTRIAL CHEMICAL CO. has named **J. E. Haughn** sales representative, Houston. He will be responsible for sales of Armour aliphatic organic chemicals in Louisiana and Eastern Texas.

B. F. GOODRICH CHEMICAL CO. has named **William H. Heinlen** marketing manager, International Department, Akron, Ohio. He had previously been acting manager of international sales for the company.

Heinlen joined The B. F. Goodrich Company in 1942 as a chemist in the company's laboratory in Akron, was in military service from 1944-46, and resumed his laboratory duties on his return.

DAVIS ENGINEERING CO. has named **Lawrence A. Nigro** New York District sales manager. He will direct sales

COREXIT stops internal corrosion--reduces maintenance costs . . .

At a cost as low as 50¢ per thousand barrels of throughput, Humble's COREXIT corrosion inhibitors will give you up to 98% protection.

You save money, because COREXIT lengthens the life of expensive equipment, prolongs refinery runs between costly turn-arounds, cuts non-productive downtime to a minimum and promotes increased thermal efficiencies.

Injected into the product stream, COREXIT establishes a durable protective film on internal metal surfaces. This film effectively protects against the causes of corrosion. COREXIT also prevents fouling.

Use COREXIT . . . You'll see a substantial cut in your maintenance costs!

COREXIT is readily available in 55-gallon drums and in bulk. Call your nearest Humble bulk plant, or phone or write:

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Consumer Sales
P. O. Box 2180
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COREXIT is also available through these companies:

In Oklahoma & Kansas:
Pet-Chem, Inc.
Mayo Building · Tulsa, Oklahoma

In Illinois, Indiana & Kentucky:
T. E. Bennett Chemical Co.
P. O. Box 245 · Salem, Illinois

In Western Canada:
Rice Engineering & Operating Ltd.
10509 - 81 Avenue · Edmonton, Alberta

HUMBLE OIL & REFINING COMPANY HUMBLE

Suppliers . . .

activities throughout New York and New Jersey. Nigro attended Syracuse University, is a graduate of the University of Rochester and has been with Davis since 1946.

KEROTEST MANUFACTURING CO. has named **Donald J. Cox** steel valve sales representative, Los Angeles. A graduate of Muskingham College, he has been with the company since 1957 as a demonstrator of Kerotest steel products in the South and West. His territory includes California, Nevada, Utah, and Arizona.

GRAVER TANK & MANUFACTURING CO. has moved its Tulsa offices to larger quarters at 2570 South Harvard St.

COOPER-BESSEMER CORP.'s Domestic Division has named **Roy W. P. Johnson** New York district manager. Previously New York District assistant manager, he will be responsible for the development of sales markets for the company's products throughout the New York domestic territory. a graduate of Kingston-on-Thames Technical College, Johnson joined Cooper-Bessemer in 1950 and has served the company's New York territory since 1951.

Johnson

THOMPSON-RAMO-WOOLDRIDGE PRODUCTS CO. has named **David L. Fellows** computer programmer. He received his B.A. degree in physics in 1949 from the University of California, Berkeley.

Prior to joining TRW Products, Fellows was an assistant mathematician for System Development Corp., Santa Monica, Calif.

HESS PRODUCTS, LTD., London, has merged with the Chemical Division of Armour Chemical Industries, Ltd. The new company will be known as Armour Hess Chemicals, Ltd., with half the share capital controlled by Armour and the other half by United Kingdom interests, including a substantial proportion by Associated Chemical Companies, Ltd.

GRAVER TANK & MANUFACTURING CO. has named **Henry H. Hemenway** director of research and engineering. A graduate of the United States Naval Academy, he was in engineering development work for Foster Wheeler Corp. for 23 years, where he headed various design functions.

BLAW-KNOX CO.'s Chemical Plants Division has named **Kenneth W. Becker** district manager, sales, Chicago District. He will headquarter in the company's sales office, Chicago. He joined the firm in 1955 to supervise the preparation of economic studies, process development, process design, and reports for various solvent extraction and deodorizing plants. Since 1957, he has been district engineer, sales, in the Midwest territory, serving primarily the fats and oils, and chemical industries.

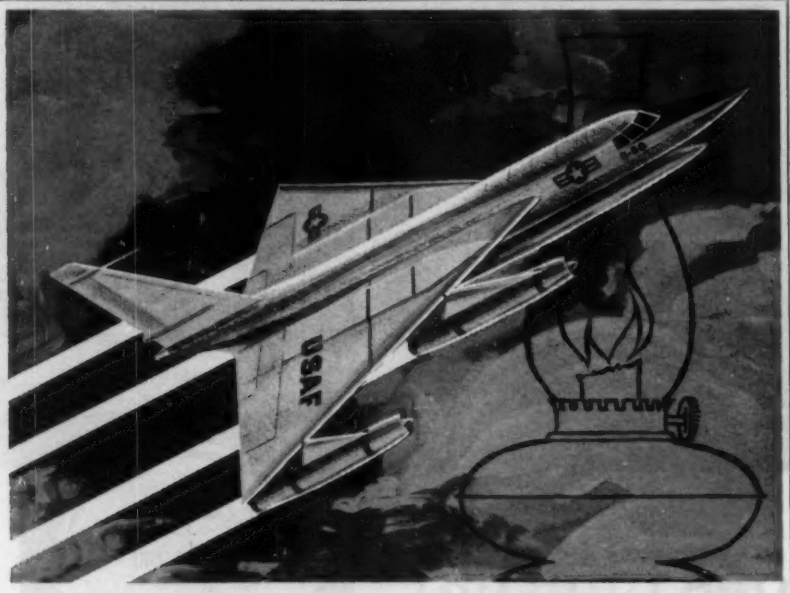
Becker

THE INDUSTRIAL INSULATORS, INC., Houston, and its branches, have been appointed distributor-applicators for the coating, sealing, and adhesive products manufactured by Benjamin Foster Co., Philadelphia.

ENGELHARD INDUSTRIES, INC. has completed an agreement with Imperial Chemical Industries, Ltd., covering the production and sale of platinum-titanium electrodes. Following the established production of platinized titanium electrodes by ICI's Metals Division, Engelhard will produce similar electrodes to replace present materials in industrial use.

B. F. GOODRICH TIRE CO. has named **John N. Brewster** manager of petroleum company sales. He joined B. F. Goodrich in 1946, having previously worked in a college training program for Socony-Vacuum Oil Company.

THE THOMPSON-RAMO-WOOLDRIDGE PRODUCTS CO. has named **Henry J. Sandler** sales engineer. He attended the University of Maryland where he received S.B. and S.M. degrees in chemical engineering. Prior to joining TRW



from **LAMP FLAMES**
to **JET PLANES**
in 100 years . . .

The petroleum industry is constantly changing its processing techniques to tailor products to the specific needs of the consumer. One outstanding example of this change is in the consumption of kerosene—from grandfather's humble flame lamp to the fuel for our nation's jet planes. The staff of The C. W. Nofsinger Company always strives to "engineer in" every possible advanced technique to provide greater processing flexibility and efficiency. When you plan new construction or plant modernization for tomorrow's needs, contact

THE C. W. NOFSINGER CO.

Engineers to the Petroleum and Chemical Industries
307 E. 63rd Street Kansas City, Missouri

Representatives
WEST COAST—A. R. Chandler, 609 S. Grand Ave., Los Angeles 17, Calif.
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In Engineering it's the People that Count

For more data on advertised products, use Readers' Service Cards, last page.

move mountains - of AIR! in towers and exchangers

- Sizes 14' to 18'
- 4 or 6 blades

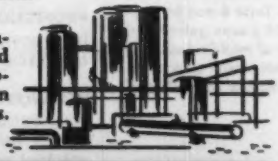
Developed originally for the petroleum industry, Aerovent Large-Diameter "Al-metal" Propellers, constructed of tough, durable aluminum alloy, move great quantities of air at high velocities, in heat exchangers and cooling towers. Pictured above are two 4-blade, 16-ft. propellers in a cooling tower installation. These mighty propellers, with adjustable-pitch "Macheta" Airfoil blades, are job-engineered to individual specifications.

Write for free Bulletin 510

DESIGNED FOR DEPENDABLE OPERATION!

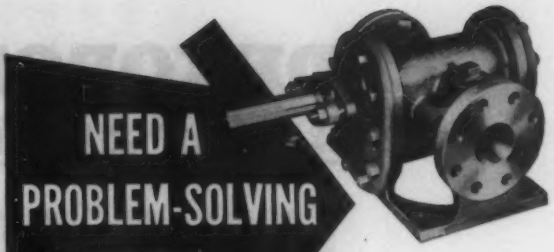
Endurance tests, conducted at *3 times* normal loading prove the ability of these new large-diameter propellers to withstand severe punishment. Heavy-duty cast steel hubs offer maximum resistance to stresses. Angle settings for each operating requirement, and appropriate alternate settings, assure accurate pitch for any predetermined performance which may be required. 54" to 144" now available in Adjustable Pitch Models.

REFINERIES, pumping stations, industrial plants and commercial buildings use Aerovent "Al-metal" Propellers in major air-moving applications.



Aerovent FAN COMPANY, INC.
LARGE PROPELLER DIVISION
304 Wright Bldg.
TULSA 3, OKLA.
Main Office and Factory
PIQUA, OHIO

NEED A PROBLEM-SOLVING PUMP?



Engineers, maintenance supervisors and plant superintendents with pumping problems swear by SK Rotary Gear Pumps. In case-after-case SK Pumps, used as original equipment or as replacements, have solved "in-service" difficulties and have given years of maintenance-free service. What these pumps have done for others, they can also do for you.

New Bulletin G-1 gives full details on standard SK Gear Pumps. Write for your copy.

Schutte and Koerting COMPANY
2257 STATE ROAD, CORNWELLS HEIGHTS, BUCKS COUNTY, PA.
Phone: MErcury 9-0900
JET APPARATUS • ROTAMETERS • GEAR PUMPS • VALVES • HEAT EXCHANGERS

RUGGED H_2 INDICATOR for catalytic reformers

Works on a simple, mechanical principle using specific gravity to measure H_2 in reformer recycle gas. Low cost. Instant response. Local or remote readings. Replaces expensive, delicate instruments that "can't take it."

Other uses: Measuring specific gravity of refinery fuel gas, off-gases from cracking furnaces, demethanizers, etc. and for gas blending . . . also analyzing boiler and heater flue gases to cut fuel costs.

• • •

Write for Technical Bulletin RD-101, The Permutit Company, a division of Pfaudler Permutit Inc., Dept. PR-9, 50 West 44th St., New York 36, New York.

RANAREX®

For more data on advertised products, use Readers' Service Cards, last page.

DEKORON
PROTECTO-PAC

Advantages of Dekoron all-plastic instrument tubing harness are *now four-dimensional.* You get, in addition to its inherent lower-cost installation . . . chemical . . . impact . . . fire resistance.

And the advantages of Dekoron Protecto-Pac multiply the closer you examine them. For example, you can get Protecto-Pac in many forms to suit your requirements exactly — *from stock.*

If there is danger from weld splatter, sparks or a potential fire hazard — order Dekoron Protecto-Pac Type FB. If you wish to bury it underground — specify low-cost Protecto-Pac Type B. Both types supplied with virtually any number of individual tubes, and also with *new metal armor protection.*

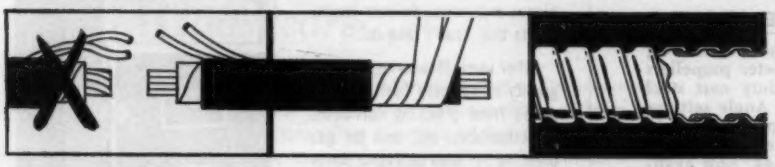
You can pay more but you can't buy better, longer-lasting instrument line harness than *Dekoron — America's Premier Instrument Tubing Line.*

AA-0986

TYPE FB
FOR FIRE AND IMPACT RESISTANCE

FIRE RESISTANCE of copper tube bundles is superior up to 1900°F; less pronounced from 1900° to 2500°F. Above 2500° Protecto-Pac Type FB is superior to copper tube bundle.

TYPE B
FOR UNDERGROUND BURIAL



NO "CORKSCREW" effect, as with twisted tubes, because tubes lie straight in bundle to give faster, neater individual tube take-offs.

NEW IMPROVED INSULATION is composed of two wraps of asbestos tape bonded to backing of Mylar® for maximum protection.

DEKORON PROTECTO-PAC Type FB or Type B can be supplied with 24 gauge galvanized steel armor of modified square-lock construction with cord packing for maximum strength and flexibility.

Dekoron® products QUALITY • RESEARCH • SERVICE

SAMUEL MOORE & COMPANY • DEKORON PRODUCTS DIVISION • MANTUA, OHIO

Suppliers . . .

Products, Sandler held engineering positions with Catalytic Construction Co., Philadelphia, and Atlas Powder Co., Wilmington, Del.

Seaver

Siegfried

BADGER MANUFACTURING CO. has named **Philip H. Seaver** sales manager, engineering sales, and **Robert E. Siegfried,** assistant engineering manager. Seaver, who has a B.Ch.E. degree from Cornell University, joined the Engineering Sales Department of Badger in 1951 following several years of process development and process engineering work. He has been a director of the company since 1957. Siegfried received his B.S. degree in chemical engineering from Lehigh University and his M.S. degree from Massachusetts Institute of Technology. Since joining Badger, he has served in the Process Engineering Department as project manager, sea water conversion program, and, most recently, as engineering coordinator.

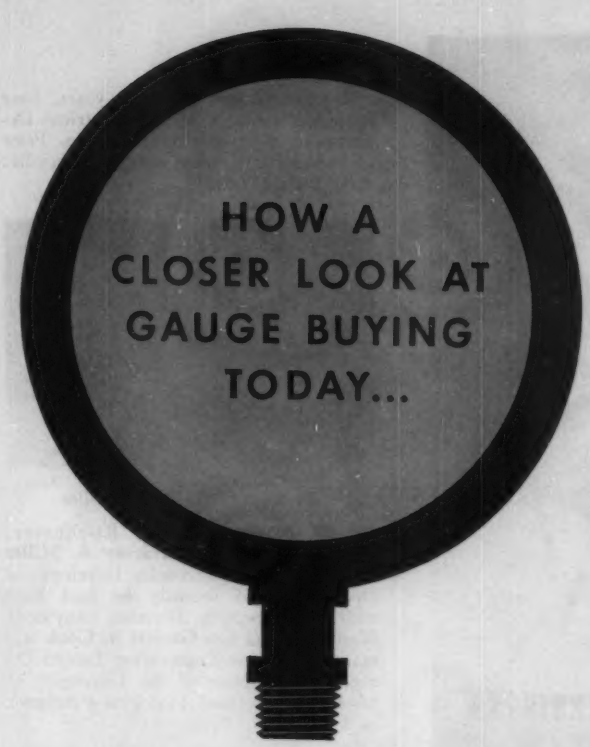
DELHI-TAYLOR OIL CORP.'s Chemical Division has named **Albert Gnesin** East Coast regional sales manager, New York. He was formerly with Divison Chemical Co. as district sales manager, and prior to that as an engineer in the Technical Service Department. From 1949-53 he was a chemical engineer in the Research and Engineering Department, Standard Oil Co. (Indiana). A chemical engineering graduate of Syracuse University, Gnesin is active in AIChE, ACS, API and the Chemists' Club.

Gnesin

PROFESSIONAL PAINTS CO., Denver, has been appointed distributor, Rocky Mountain area, by Truscon Laboratories.

WALWORTH CO. has organized a French corporation to manufacture and sell valves for pipe-lines in France and her colonial possessions. Called Grove-France, S. A., the firm will be managed by **Marvin H. Grove,** president of Grove Valve and Regulator Co., Walworth subsidiary.

ALLIS-CHALMERS MANUFACTURING CO. has appointed **George A. Saar** assistant to **J. L. Singleton,** vice president of the



can save up to 40% on many pressure gauge applications

Analyzed your gauge needs lately—how much gauge performance you're getting, compared to what you need and what you pay for? Perhaps it's time for a closer look at United States Gauge with its line of 50,000 standard pressure gauges, plus specials (and all possible choices in case styles, sizes, materials and pressure ranges). For example, note how you can save up to 40% on premium gauges and still get premium performance with the USG A-Line *(top, right)*. Note, too, how you can get the exact gauge for *any* need and cut waste of under-buying or "over-gauging" . . . from all the gauge lines available at this one source. Then check the USG distributor listed in your Yellow Pages. Or write direct for catalogs and name of your nearest distributor today.

Paying needless premium prices for reliability? USG A-Line pressure gauges have premium construction, save up to 40% on premium prices. Meet A.S.A. Grade A standards, including 1% accuracy. Extra rugged, they are built to *deliver* longer under severe operating conditions, where you do not require the accuracy of Grade AA gauges, but where reliability and cost-cutting are "musts". Wide choice of Bourdon tubes, case styles and sizes, pressure ranges, and movements. You must see the sturdy design and price to believe the value and performance. Models for general-purpose service, altitude, refrigeration, ammonia and hydraulic applications. *Write for Catalog 305.*

Buying too much gauge for your purpose? Save with volume-priced, precision-built USG Drawn Case Gauges for service where your gauge need calls for A.S.A. Grade B standards, including 2% accuracy. *Write for Catalog 64A.*

Getting all the accuracy you're paying for? You can't buy more precision than with USG Test Gauges which meet or exceed A.S.A. Grade AA standards, including accuracy as high as 0.2 of 1%. *Write for Catalog 400.*

USG **UNITED STATES GAUGE**
Division of American Machine & Metals, Inc., Sellersville, Pa.

Find Your Nearest Distributor in the "Yellow Pages"

AIRETROL pneumatic tube expansion control shown. Electric systems, including retractive units, also available.

WITH AIRETOOL TUBE EXPANSION CONTROLS, WORKERS ROLL MORE TUBES PER DAY. THEY JUST PRE-SET A DIAL AND THE TOOL SHUTS OFF AT DESIRED TUBE EXPANSION. *ACCURACY?* WITHIN .001" EVERY TIME. ELIMINATES OPERATOR ERROR. OFTEN DOUBLES DAILY PRODUCTION. WRITE FOR PLANT DEMONSTRATION OR BULLETIN.

AIRETOOL
MANUFACTURING COMPANY
SPRINGFIELD, OHIO

BRANCH OFFICES: New York, Chicago, Philadelphia, Tulsa, Houston, Baton Rouge.
REPRESENTATIVES in principal cities of U.S.A., Canada, Mexico, Puerto Rico, South America, Hawaii, England, Italy, Europe, Japan.
CANADIAN PLANT: Brantford, Ontario
EUROPEAN PLANT: Vlaardingen, The Netherlands

Suppliers . . .

Industries Group. For four years, Saar has been manager of the Electrical Department, Norwood, Ohio, works. Prior to that he had been works comptroller there for six years.

Cook

Miller

TAYLOR INSTRUMENT CO., Rochester, N. Y., has appointed **Harvey A. Miller** manager of its Electronics Development Division. Until recently he had been with the Research Division, Raytheon Manufacturing Co. **Garrett A. Cook** will manage the new Engineering Design Division. A graduate of the University of Michigan, he joined Taylor as a designer in 1945.

THE BABCOCK & WILCOX CO.'s Tubular Products Division has named **Robert E. Halloran** Pacific Coast sales manager, Los Angeles. He joined B&W in 1941 as a student engineer. He then became a salesman in the division's New York district sales office, and in 1953 was appointed manager of mechanical sales for the division. Halloran is a graduate of Case Institute of Technology.

Halloran

U. S. INDUSTRIES, INC., has advanced **R. D. O'Brien** to group executive for the two Petroleum Equipment Divisions. Until recently, he was secretary of USI. O'Brien will direct the Garrett Oil Tools and Axelson Divisions, and will assist the autonomous management of each division. Before joining USI, O'Brien was with the law firm of Baldwin, Todd & Lefferts of New York City. He is a graduate of St. Lawrence University and Columbia Law School.

O'Brien

DAYSTROM-WESTON SALES DIVISION, Daystrom, Inc., has named **Ross K. Patterson** manager, Northwest District. He will supervise all sales and district office operations for that sales division, including Washington and Oregon. With Weston 12 years, Patterson received an electrical

For more data on advertised products, use Readers' Service Cards, last page.

7 powerful steps to high octane

Into one end of this big reactor flow refinery streams almost worthless as automotive fuels. Out the other end runs a river that's rich in high-octane alkylate.

Squatting atop the reactor are seven 50-hp LIGHTNIN Mixers. From each one, a turbine-equipped steel shaft reaches down to whip into an emulsion the isobutane feed, the recycle olefins, and the viscous sulfuric acid catalyst.

Mixing is the heart of this process. With the LIGHTNIN Mixers, every cubic inch of each reaction zone gets a violent, steady churning. Controlled turbulence instantly disperses the incoming olefins. It keeps the emulsion homogeneous, prevents separation of hydrocarbon in any part of the reactor, promotes acid economy and light alkylate yield.

At this one refinery, 28 of these big LIGHTNIN Mixers run day in, day out on alkylation reactors. At other refineries, many more LIGHTNIN Mixers handle the same vital mixing job.

To earn this acceptance, MIXCO engineers studied alkylation processes intensively; made detailed model tests of agitation flow patterns in simulated reactor systems; applied specialized knowledge of the correct loading of mixer impellers to operate under varying reactor conditions.

The same mixing technology is ready to work for you when you specify LIGHTNIN Mixers—whether for a new process, for blending 180,000 barrels of product, for keeping sediment off the bottom of crude storage tanks, or for any of the thousand and one jobs LIGHTNIN Mixers do every day in refineries.

Your LIGHTNIN representative can give you quick, competent help on fluid mixing. He's listed in Refinery Catalog and in the yellow pages of your telephone directory. Or write us direct.

Lightnin® Mixers

MIXCO fluid mixing specialists

MIXING EQUIPMENT Co., Inc., 164-j Mt. Read Blvd., Rochester 3, N.Y.

In Canada: Greey Mixing Equipment, Ltd., 100 Miranda Ave., Toronto 19, Ontario

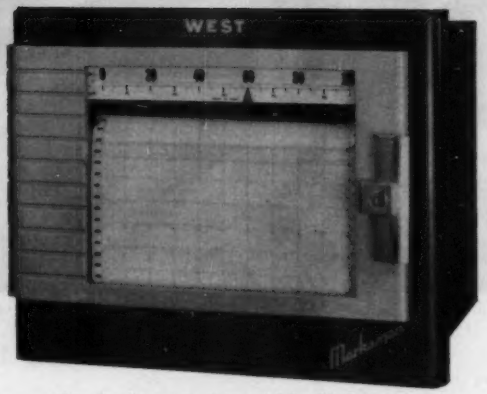
Still hitched to horse-and-buggy recorders?

Boost volume...
assure quality...
control costs
with

Marksman

Tubeless Strip-Chart Potentiometer Recorders

See us at the 14th Annual Instrument-Automation Conference & Exhibit International Sept. 21-25, 1959 International Amphitheater-Chicago Booths 324-326



Transistorized, these precise instruments avoid *all* the notorious tube-troubles. Needing no warm-up, adjustment, replacement of tubes or repair of their circuitry, Marksman recorders permit immediate and *continuous* operation...so increase production.

Accurate within 1/5th of 1%, they also include several special features which provide for more user-convenience and consistent quality-control. Users in many lines report Marksman recorders involve less operational cost, as well as reducing waste of other factors.

Let our world-wide service help on your own job. Phone your West consultant (see Yellow pages) or write Chicago office for Bulletin M.

WEST *Instrument*
CORPORATION
SALES OFFICES IN PRINCIPAL CITIES
FACTORY AND GENERAL OFFICES:
4351 W. MONTROSE, CHICAGO 41, ILL.
BRITISH SUBSIDIARY
WEST INSTRUMENT, LTD.
52 Regent St., Brighton 1, Sussex

the trend is to **WEST**

Suppliers . . .

engineering degree from Oregon State College and did post graduate work in diesel engineering at Cornell University. Before joining Weston, he was a commercial radio operator for the Alaskan fishing industry and was an instructor at the University of California.

CONSOLIDATED ELECTRODYNAMICS CORP. has named **S. R. Wyzenbeek, Jr.,** manager of the Palo Alto, Calif., District sales office. He was formerly manager of the San Diego district office.

ACF INDUSTRIES, INC.'s W-K-M Division has named **C. Ross Spencer** manager, special projects. Formerly with the Oil Center Tool Co., he had previously been with the National Supply Co. Spencer is a graduate of The University of Texas.

ARMOUR INDUSTRIAL CHEMICAL CO., a new grouping, has been formed and has moved its management and sales personnel to new and larger quarters at 110 North Wacker Drive, Chicago.

THE OKONITE CORP.'s James F. Angle has been appointed district manager, Salt Lake City District office, Surety Life Bldg., 1935 South Main St. He was previously in the Los Angeles office.

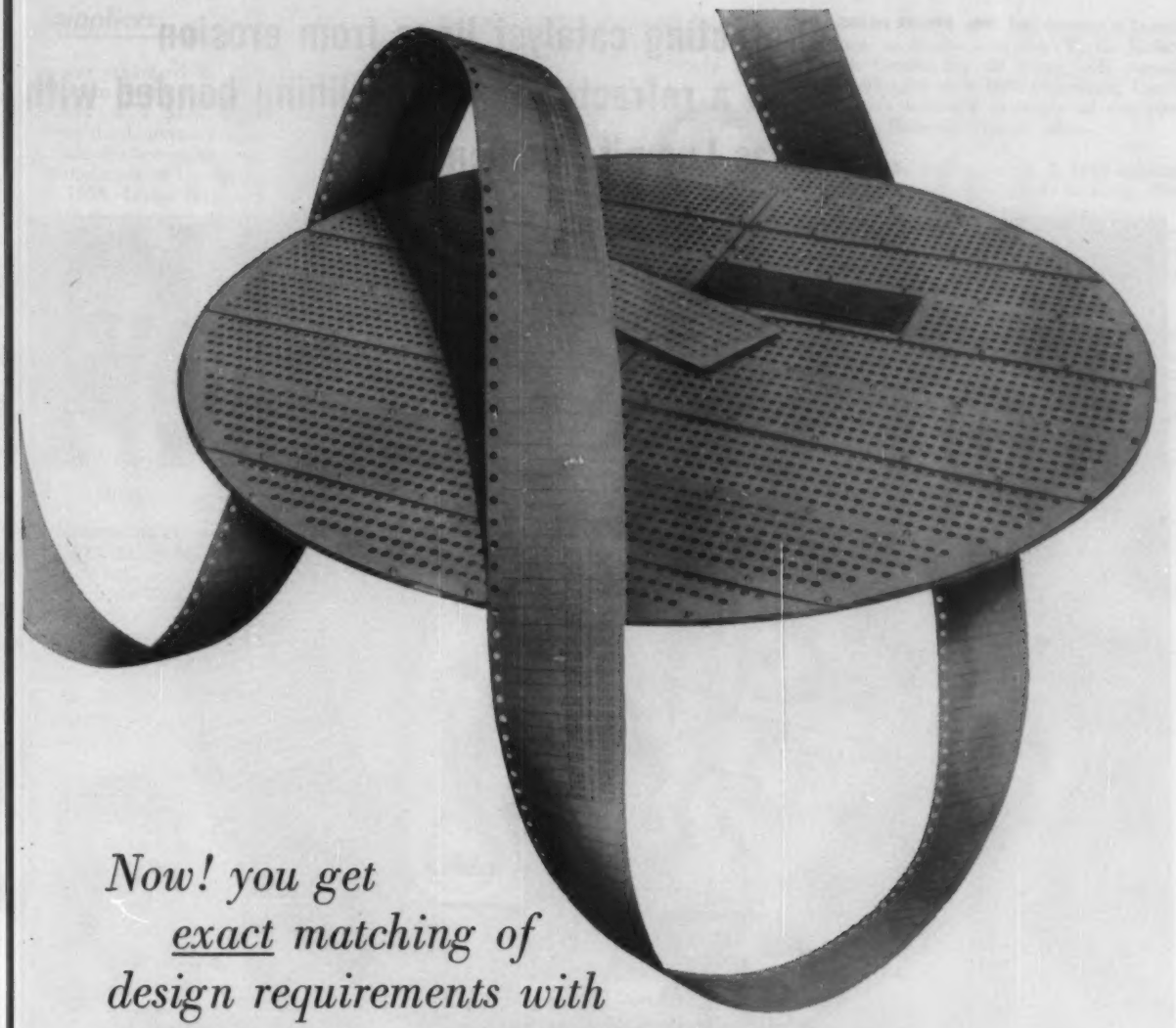
WALWORTH CO. has named **Leroy Snell** sales representative in the firm's Gulf Division. Southern Louisiana will comprise his territory. Before joining Walworth, Snell was manager for one of Louisiana's major supply companies.

CRANE CO. has elected **Wesley A. Songer** executive vice president. He had been executive vice president of American Safety Razor Corp., and before that was on the president's staff, General Electric Corp. Songer joined American Safety Razor as vice president and general manager of operations in 1952 and a year later was named executive vice president and a member of the board and of the executive committee. He received a B.S. degree from the University of Kansas in 1940 and a M.B.A. degree from Harvard University in 1947.

Songer

LEEDS & NORTHRUP CO. has named **William C. Roxby** manager of the Foreign Sales Division, Philadelphia. With L&N for more than 33 years, he is a director of Foreign Traders Association of Philadelphia. Formerly assistant manager of foreign sales, he succeeds **E. B. Estabrook,** who becomes a consultant.

CHEMETRON CORP.'s Girdler Catalyst Unit, Chemical Products Division, has named **Merle R. Likins** technical service engineer, Louisville. Likins had been head of Girdler's Houston branch office since



Now! you get
exact matching of
design requirements with

HENDRICK COMPUTER-RATED COLUMN INTERNALS!

When your design figures are fed to our electronic computer, they're quickly turned into column internal specifications that provide maximum operating efficiency. That's why Hendrick Perforated Trays can offer you these important advantages:

- Smaller column diameter for a given process capacity.
- Lower initial cost.
- Higher vapor thru-put.
- Less entrainment
- Simpler tray construction.
- Easy maintenance.
- A wide range of stable operation.

Available in all types of commercially rolled metals. Stainless steel or other corrosion-resistant metals are recommended for corrosive services. As a result, you can now cut replacement costs and production losses caused by downtime, changeovers or cleaning – just by working with Hendrick engineers.

HENDRICK MANUFACTURING COMPANY

Perforated Metal • Perforated Metal Screens • Wedge Slot and Hendrick Wedge Wire Screens • Architectural Grilles • Mitco Open Steel Flooring • Shur-Site Treads • Armorgrids • Hendrick Hydro-Dehazer • Distillation Column Internals

Hendrick is licensed to manufacture ESSO "Jet-Trays," SOCONY "Uniflux," SHELL "Turbo-Grid" and STONE and WEBSTER "Ripple" Trays. Hendrick is also equipped to supply all types of trays to specifications.

Manufacturers of Catalyst Support-Perforated Screen Beds

Hendrick Manufacturing Company
36 Dundaff Street, Carbondale, Penn.

Gentlemen:

☐ Please send FREE Bulletin C1-2
☐ Have representative call

Title_____ Name_____

Company_____

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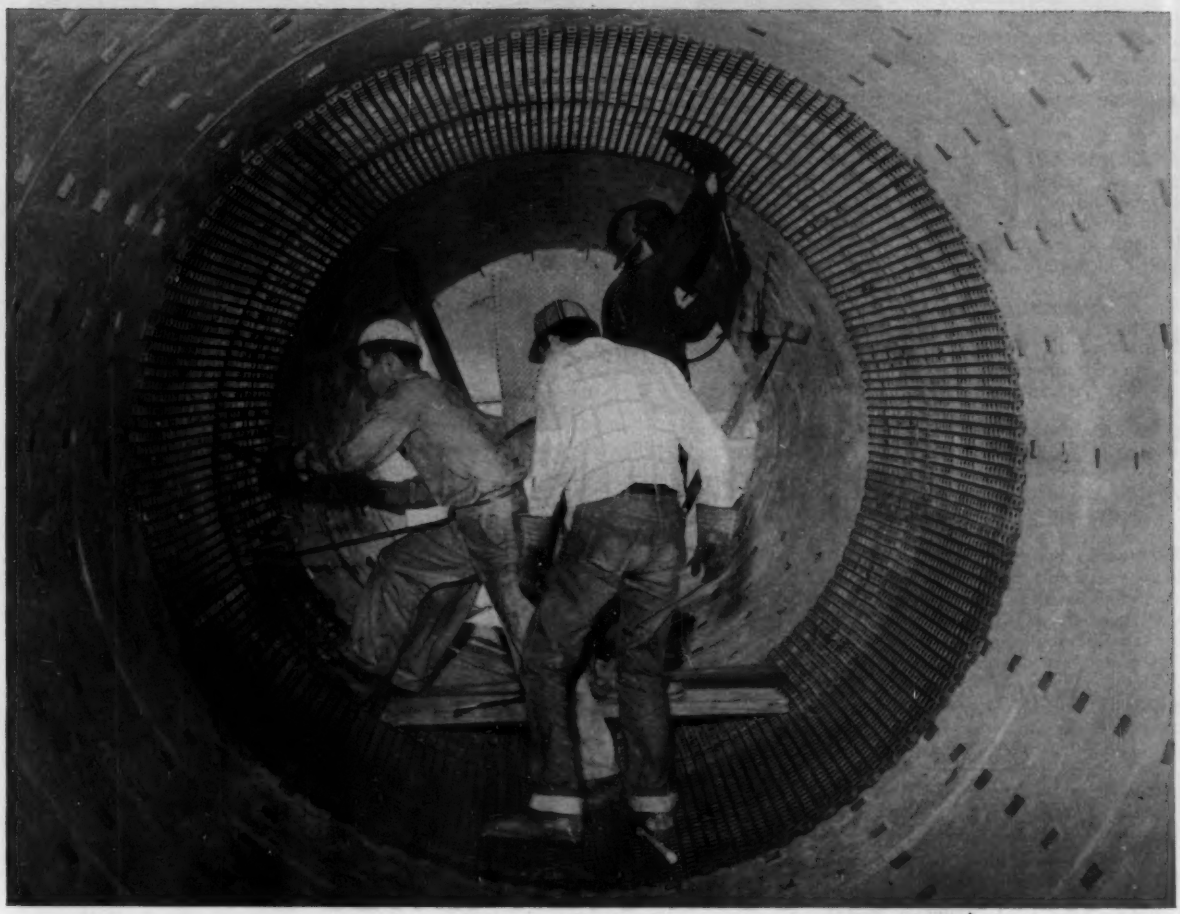
City_____ State_____

For more data on advertised products, use Readers' Service Cards, last page.

Protecting catalyst lines from erosion with a refractory castable lining bonded with Atlas Lumnite Cement



Gunite Contractor: J. A. McCollum, Inc., Marlton, N. J. Castables: Mexico Refractories Co., Mexico, Mo.

In this catalyst line at a large Gulf Coast refinery, steel mesh is being welded into place over a 3-inch lining of insulating refractory castable bonded with Lumnite calcium-aluminate cement. Over the mesh, a 1-inch thickness of high-strength castable will be gunited, providing a 2-component refractory concrete lining that will resist severe erosion and abrasion caused by catalyst fines. Monolithic refractory concrete linings eliminate troublesome mortar joints. They are easily placed, conforming to any contour. Castables are recommended because they are simply mixed with water and placed – concrete reaches service strength in 24 hours. Castables containing Lumnite cement are available from leading manufacturers of refractories for a variety of applications in refinery equipment. For information, write Universal Atlas, 100 Park Avenue, New York 17, N. Y. "USS," "Atlas" and "Lumnite" are registered trademarks.

USS **Universal Atlas Cement Division of United States Steel**

L-184

OFFICES: Albany • Birmingham • Boston • Chicago • Dayton • Kansas City • Milwaukee • Minneapolis • New York • Philadelphia • Pittsburgh • St. Louis • Waco

Suppliers . . .

it was organized in 1958. A graduate of Western Kentucky State College, and holder of a M.S. degree in chemistry from the University of Louisville, he was a senior chemist at Clayton & Lambert Manufacturing Co. before joining Girdler in 1955. Likins is a member of ACS.

Sharp

Morris

CONTINENTAL-EMSCO CO. has named **William G. Sharp** manager, Export Division, New York, and **JoEarl Morris** manager, Continental-Emsco Co. C. A., Caracas, Venezuela. Sharp has been with Continental-Emsco since 1947 and was previously manager of its Venezuelan company.

Morris, with the firm 19 years, was formerly assistant manager, Continental-Emsco Co. C. A.

Brouillard

Webb

GENERAL ANALINE & FILM CORP.'s Dyestuff and Chemical Division has named **Dr. Robert E. Brouillard** sales manager, pigments, and **H. Alison Webb** sales manager, Dyestuffs. Dr. Brouillard graduated from Bates College, Maine, in 1938 and received his Ph.D. degree from Clark University in Massachusetts in 1941. After several years with American Cyanamid Co., he joined GAF in December, 1948, at the Linden plant and moved to New York as assistant manager of the Pigment Sales Department in February, 1957. In January, 1958, he was named product manager, pigments.

Webb joined the company in 1935 after graduating from Clemson College in South Carolina. After serving in both technical and sales capacities in the Charlotte office for many years, he was appointed manager of the Chattanooga office when it was opened in January, 1954. He came to New York as assistant sales manager, dyestuffs and pigments, in October, 1957.

BLAW-KNOX CO., Pittsburgh, has named **George E. Kopetz** vice president and general manager of the newly formed Fabricating, Engineering and Construction Group. **Arthur E. Murton,** formerly roll sales vice president, has been appointed vice president and general manager of the new Foundry & Mill Machinery Group. **H. G. Coffey** heads the company's third operating group as vice president and general manager of the Aetna-Standard Division.

Kopetz

GOULDS PUMPS, INC. has opened a branch office in Shreveport, La. **T. G. Kelley,** with Goulds for 30 years, will manage the office, to be at 1007 Petroleum Tower. He was formerly manager of the company's Houston branch office.

LINDE CO. has named **J. J. Dall** assistant general manager, electric welding, New York. Formerly general manager of a smaller Linde department where these electric welding processes were used extensively, Dall has been with the firm since 1946.

BAILEY METER CO.'s J. W. Cunningham has been named manager of the Atlanta District office. He joined the company in 1947, after graduation from Clemson College, and has been on the Atlanta staff since 1948.

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12001 HIRSCH ROAD • HILLCREST 2-2537
P. O. BOX 11286 • HOUSTON 16, TEXAS

For more data on advertised products, use Readers' Service Cards, last page.

Suppliers . . .

THE U. S. STONEWARE CO. has named **David H. Pyle** sales representative, Philadelphia territory. Previously senior service engineer in the Philadelphia district, Hall Laboratories Division, Hagen Chemicals & Controls, Inc., he received his B.S. degree in chemistry from Akron University.

CENTRAL SCIENTIFIC CO. has named **James A. Schaefer** manager, Houston branch. He formerly was Pittsburgh representative for the company, which he joined in 1950 as an assistant in the Purchasing Department.

Hill

Ehret

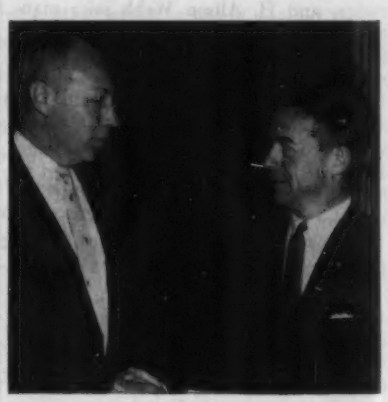
EHRET MAGNESIA MANUFACTURING CO., Valley Forge, Pa., and Baldwin-Hill Co., Trenton, N. J., have filed a merger agreement. The new company is known as Baldwin-Ehret-Hill, Inc., with home offices at 500 Breunig Ave., Trenton. Officers of the new company are: **William H. Hill,** chairman of the board; **Alvin M. Ehret, Jr.,** president; **Edward R. Stevens,** executive vice president; **Henry E. Howell, Harold L. Humes** and **Miles M. Wilson,** vice president; and **William A. Schreyer,** secretary-treasurer.

COOPER-BESSEMER CORP. has named **Donald L. Reed** manager, packaged compressor sales, Mount Vernon, Ohio. He will also remain product manager for gas engine compressor sales. A graduate of the University of Cincinnati, Reed has a mechanical engineering degree. He first joined Cooper-Bessemer in 1948 while a co-op student at the University of Cincinnati, and joined the company in 1953. He was made manager of gas engine compressor sales in 1954.

Reed

ROCKWELL MANUFACTURING CO. has formed a Governmental Relations Department with responsibility of keeping abreast of legislative, political and tax affairs in the United States and throughout the world. **I. C. Rowe,** formerly corporate secretary, has been named director. In the legal and accounting fields for 35 years, he has been secretary of Rockwell since 1951. He joined Rockwell in 1941 as a tax accountant and became assistant secretary in 1948. Rowe received his legal training at St. Louis University and the City College of Law in St. Louis.

Rowe



MALONEY-CRAWFORD TANK AND MANUFACTURING CO. has purchased the entire Union Tank Division, Houston, of Butler Manufacturing Co.

R. C. Schenk, left, president of Ma-

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(Zinc Chromate Organics)

- ✓ Proved in Cooling Systems for over 11 years
- ✓ Safe pH Ranges
- ✓ No Sludge Precipitate
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Through many years of experience Wright Engineering has developed Wright Penechromes as an effective answer to corrosion . . . if you have a common or "special" problem, write for an engineering survey of your water using equipment. A comprehensive conditioning program by Wright will pay big dividends.

Write us on your company letterhead for the new Wright Cooling Water Calculator—it quickly calculates operational data.

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Offices in Principal Cities
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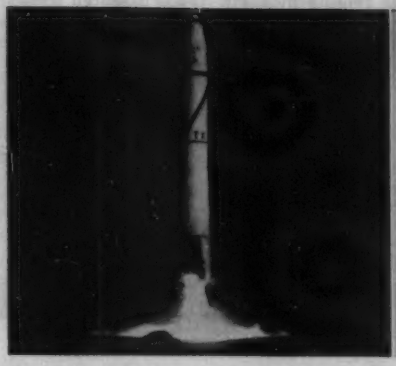
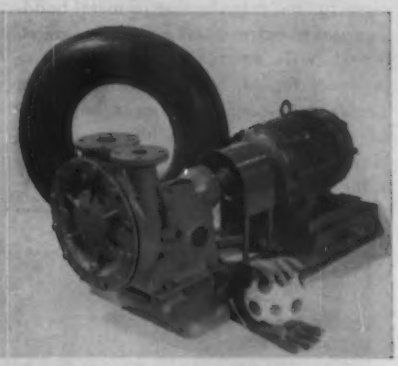
Wright CHEMICALS

PUMPAGE

Goulds news about pumps for process industries





Rocket's red roar

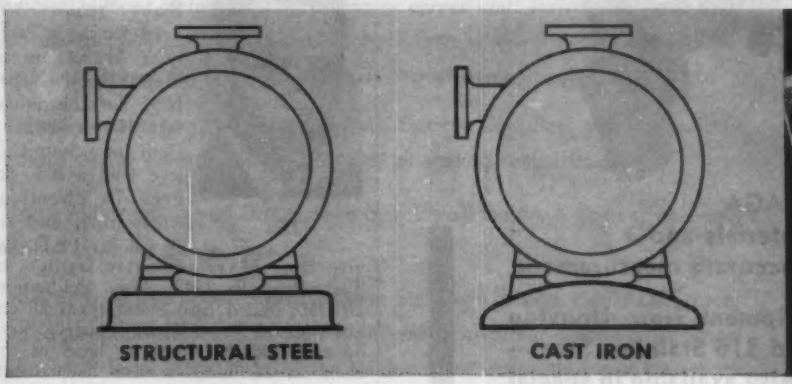
After the countdown—a roaring and soaring! The fuels that make rockets roar contain highly abrasive solids, ignite and burn rapidly with the slightest contact with air or oxygen. Handling them is a problem—pumping temperatures run as high as 550° F. For one government installation, Goulds developed a vertical process pump with an inert gas chamber that is used as a barrier between pumpage and rotating shaft seal. Gas pressure is maintained by an automatic purgerator slightly above suction inlet pressure to insure no contact between the mechanical seal and the abrasive solids. This pump has been found so broadly applicable that it is now a standard model in our line.

Now . . . a centripetal pump!

A unique use of centripetal action lets Goulds Fig. 2520 handle liquid, air, or liquid *and* air! The centrifugal force of the impeller separates the liquid from the lighter air, which accumulates at the center of the impeller and casing. The liquid, circulating at the casing periphery, is directed (by centripetal action) toward the center, pushing the air ahead of it and through the discharge. Once primed, this pump *stays* primed! It can't air bind—even with loops or leaks in your suction line. Handles foaming solutions and emulsions easily. You can use it for almost anything: as a scavenger, for transfer work, for cleaning up, for pilot plant work. Ask for Bulletin 725.6 for all the details!

Latex: Handle with Care

Before synthetic latex can become the bouncy consumer products you see here, it must be a fairly instable liquid, able to gel or coagulate easily. For that reason, a pump must handle latex gently or the impeller will clog and have to be cleaned frequently. Such a pump is the Goulds Fig. 3715—six of which are presently being used by a rubber manufacturer to transfer latex from storage tanks to tank cars and in the latex concentrator line. A semi-open impeller allows a minimum of mechanical shock or friction at optimum efficiency. Normal cleaning operations are performed easily, because the casing cover and impeller can be easily removed without disturbing pipe connections. Bulletin 725.4.



Cast-iron bedplates

A rigid well-grouted bedplate under your pump and driver is the first requirement for trouble-free operation. Accordingly, Goulds furnishes rigid corrosion-resistant cast-iron bedplates as standard at no extra cost. The Goulds special camber top prevents accumulation of corrosive liquids. The camber design with its large accessible grout hole at the high point insures complete fill-up of bedplate cavity with grout. This economical design, jig-drilled for pump and motors, provides integral motor pad, eliminating costly separate motor base.

Get all the news monthly—FREE!

If you've liked reading about the new designs and applications of pumps as presented on PUMPAGE, then you'll appreciate getting a sister publication, GOULDS NEWS, mailed to you free every other month. GOULDS NEWS is a 4-page newsletter that highlights new developments in pumps and profitable ways that they are used. You can add your name to our mailing list by merely writing, on your letterhead, to Goulds Pumps, Inc., Dept. PR-99, Seneca Falls, N. Y.

GOULDS PUMPS

Suppliers . . .

loney-Crawford Tank and Manufacturing Co., Tulsa, confers with **John A. Morgan,** president of Butler Manufacturing Co., Kansas City, Mo., before the purchase. Butler will retain the Houston plant for the manufacture of metal buildings and other products and, for a limited period, will continue to manufacture products for Maloney-Crawford. Union Tank's engineering, product and field sales operations will be integrated with Maloney-Crawford's Tulsa headquarters in the near future.

Behr

White

BABCOCK & WILCOX CO.'s Boiler Division has named **Ralph K. Behr** manager of the New York district sales office. Replacing him as manager of the division's Boston District sales office is **Gerald S. White,** former sales engineer, Boston. Behr joined B & W in 1928 as a member of the New York engineering staff. He became a sales engineer in the Chicago district in 1937 and was appointed manager of the Boston district in 1954.

White joined the company in 1937 as a student engineer in Barberton. After employment in the Pittsburgh Service Department, he transferred to the Boston office as a sales engineer in 1946.

Spiry

McCabe

THE KENDALL CO. has named **Alfred J. Spiry** manager of the Polyken Sales Department, International Division. He will headquarter at 222 West Adams St., Chicago, where his activities will include all phases of the company's overseas marketing. **Donald W. McCabe,** previously responsible for the marketing of Polyken products by The Kendall Co. in Canada, has joined Polyken Protective Coatings, Chicago, as assistant merchandise manager.

ENJAY CO., INC. has elected **Robert K. Dix** vice president. He succeeds **H. J. Rose,** who has become a vice president of Esso Export Corp. Dr. Dix, who was formerly assistant general manager of Esso Standard's Baton Rouge refinery, will head Enjay's Products Management Department from New York headquarters. He graduated from Iowa State College with a B.S. degree in chemical engineering, and received his Ph.D. degree from Massachusetts Institute of Technology in 1943. After graduation, Dr. Dix joined Esso Standard as an engineer at the Baton Rouge refinery, where he subsequently served as head of the chemical technical service department. From 1953-57 he held rotational assignments, which included positions as head of the Technical Division, and as operating superintendent of the refinery. He was named assistant general manager in 1957.

Dix

COOPER-BESSEMER OF CANADA, LTD. has named **E. D. Van Fossen** and **R. L. Moore** to division managerial posts. Van Fossen becomes Western District manager and will direct his operations from a company field office in Calgary. Moore, in his new post as Eastern District man-

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Orifice Plates are bored to AGA Specifications of quality materials and precision workmanship for accurate measurement.

Available for immediate shipment from Houston stock in – Type 302, 304 and 316 Stainless Steel – Brass – Bronze and Monel. Also available in special sizes and materials to Customer's specifications.

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For more data on advertised products, use Readers' Service Cards, last page.

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Cut disconnect-reconnect time by as much as 50%

The FALK Spacer Coupling is specially designed for quick installation or removal *without disturbing the driving or driven unit.* This feature can save you up to 50% in disconnect-reconnect time when critical equipment—a process pump, for example—needs repair or replacement.

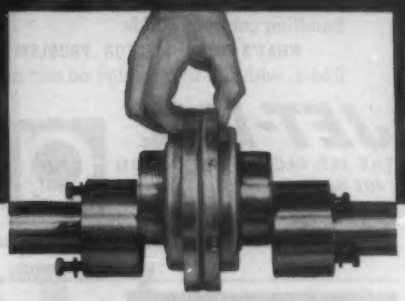
Here's another saving: with the FALK Spacer Coupling, you can quickly realign shafts *without the usual loss of operating temperature!*

And still another: you can remove or reinstall the FALK Spacer as a unit *without draining the lubricant.*

Because of its exclusive grid-groove Steelflex design, the FALK Space. can accommodate residual misalignment—parallel, angular, or (most important) *both.* Also, it provides torsional resiliency that cushions shock and vibration. Thus it saves wear-and-tear on your connected equipment.

To prove these claims and enjoy these savings, install a FALK Spacer on one application—and see for yourself. Consult your FALK Representative or Authorized Distributor.

THE FALK CORPORATION, MILWAUKEE 1, WISCONSIN
MANUFACTURERS OF QUALITY GEAR DRIVES AND FLEXIBLE SHAFT COUPLINGS
Representatives and Distributors in many principal cities.

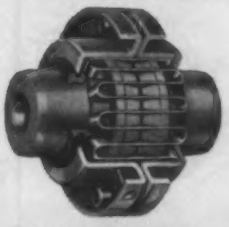


EASY AND QUICK TO INSTALL, DISCONNECT OR RECONNECT

First, mount shaft hubs to allow proper distance between hubs; then, align driving and driven units.

Second, compress Spacer to fit space between hubs and tighten cap screws to pull spacer hubs into the registered fit.

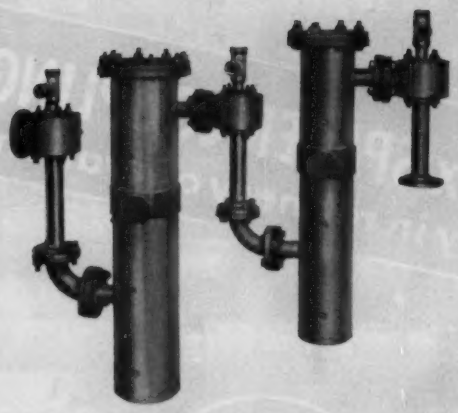
To disconnect, reverse the second step. No draining of lubricant necessary.



The heart of the FALK Spacer ...the basic Type F Steelflex
Write for Service Manual 4838

FALK
...a good name in industry

a jet for every job



Corrosive fluid handling problem? There's a Jet-Vac ejector that will solve it efficiently and at low-cost.

Like this 3-stage Jet-Vac ejector, for example. Its stainless steel constructon affords better internal and external corrosion resistance, lighter weight.

Jet-Vac ejectors can be made with super alloys, many other special corrosion resistant materials which give a new measure of protection for handling corrosive fluids.

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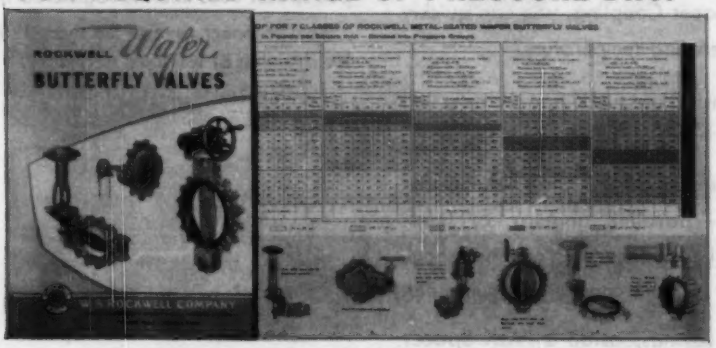

This new Bulletin No. 583 gives all the facts to help you select just the size and construction of valve for your air, gas or liquid lines. Illustrations—charts—tables are arranged in a practical, easy-to-use manner. Write for your copy.

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Valves - Butterfly · Slide · Diaphragm · Special
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Suppliers . . .

ager, will operate from offices in Toronto. Van Fossen holds a mechanical engineering degree from the University of Washington, while Moore is a graduate of the University of Toronto.

MINNEAPOLIS-HONEYWELL REGULATOR CO.'s Beltsville, Md., division has named **Kimball C. Cummings** manager of engineering. Formerly associate director of research, Aeronautical Division, he has responsibility for design and development of magnetic tape systems and components for the instrumentation and data-handling fields. After joining Honeywell's Research Division in 1947, Cummings assisted in the development of electromechanical computers and simulators for aerial navigation, home heating and relative humidity. He also was head of a research group concerned with inertial navigation systems and components, minute systems, digital techniques and instrumentation.

Cummings

FISCHER & PORTER CO. has named **Daniel S. Steelman** director of purchasing. Formerly purchasing agent for the company, Steelman has been with F & P 17 years. In addition to being responsible for the procurement of all production, maintenance - repair - operating, capital and construction material, he directs purchasing for subsidiaries. Steelman has a B.S. degree in industrial management from LaSalle College, Philadelphia. He is a member of the National Association of Purchasing Agents, Philadelphia Association of Purchasing Agents, American Society for Metals and Research Institute of America.

Steelman

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READERS' SERVICE CARDS*
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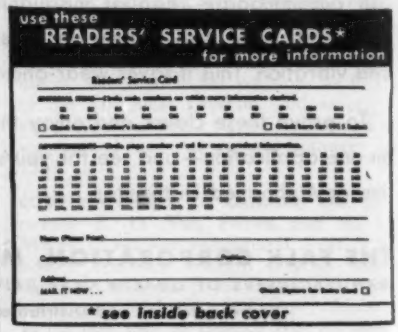


* see inside back cover

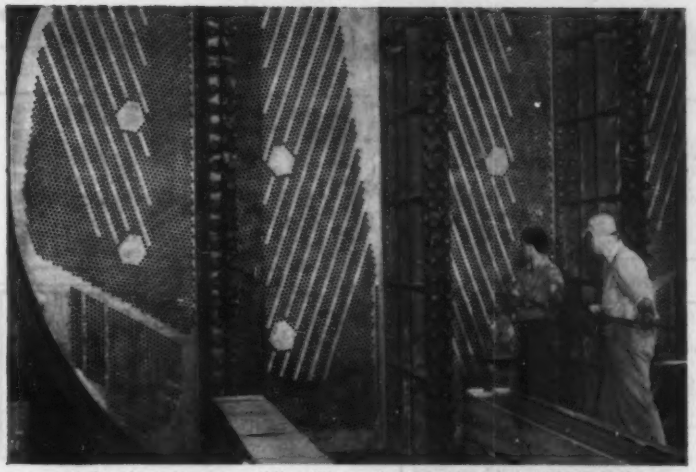
SMALL!

Small tubes like these for oil heaters and coolers are precision-made, give unexcelled service.

BIG!

Chase regularly supplies quality tubes in a wide range of alloys to fabricators of units such as this 25,000 sq. ft. condenser, shown here under construction.

BIGGEST!



Cycles of retubing vast public utility condensers using around 100 tons of tubes are far less frequent when long-lasting Chase tubes are selected.

Chase Heat Exchanger Tube Service Is Complete!

Need a dozen small tubes in a hurry for a replacement job—Or 100 TONS for a new installation? Chase is geared to give you the best possible service in either case. Warehouse and mill stocks enable us to meet emergency schedules. Mill facilities are geared to turn out big orders quickly.

Chase offers one of the most complete selections of condenser and heat exchanger tube alloys to meet any condition, and in a wide range of sizes. We can supply U-Bends, tubes with thickened centers or thickened ends, bi-metal, etc.

Call or write the nearest Chase Warehouse or Chase Sales representative.

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FITS ALL BI-METALLIC WELLS

FULL 3½" DIAL FACE

Check these functional features

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- Stem can be placed at any desired angle and case can be rotated to most readable position.
- External calibration for zero setting.
- Unaffected by stem alignment.
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- No sticking at any temperature.
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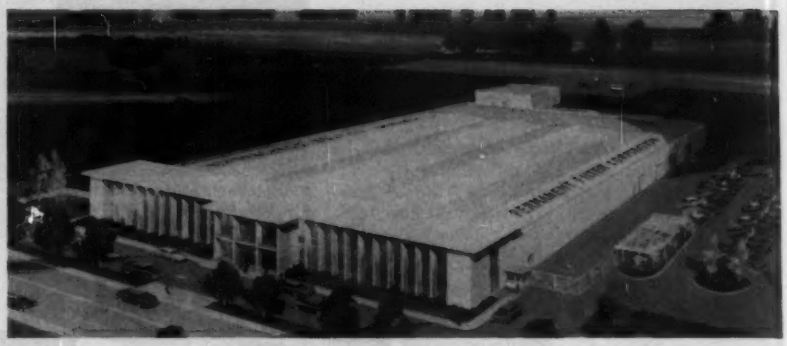

Permanent Filter Corp. has broken ground for its new $1.25-million manufacturing plant and headquarters offices to be constructed in Oxnard, Calif. Located at Fifth St. and Patterson Road on a 10-acre site adjacent to the Oxnard Airport, the projected facility will consolidate all of Permanent Filter's manufacturing, research and development and central office activities presently headquartered in Los Angeles.

Petroleum Refiner Classified Ads

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HELP WANTED

■ For UNION CARBIDE CORPORATION—Engineer or chemist with 3-10 years' petroleum process or products experience to buy lube oil, fuel oil, solvents, waxes, coke, etc., in Central Purchasing Dept. N.Y.C. location. Send resume to E. J. Corry, Room 102, 30 E. 42 St., N. Y. 17, N. Y.

CHEMICAL ENGINEER

. . . with strong background or recent practical experience in statistical analysis and design of experiments for staff position in development division of a growing organization. Age 25 to 40. Excellent opportunity for an energetic and creative engineer. Reply D. C. Williams, Manager-Development Division, United Carbon Company, Aransas Pass, Texas.

POSITION WANTED

■ Chemical engineer, age 30, family, with eight years experience in design engineering, construction, and operating departments of major refinery and chemical plant construction firm seeks position with less moving. Box 320-R, PETROLEUM REFINER, Houston, Texas.

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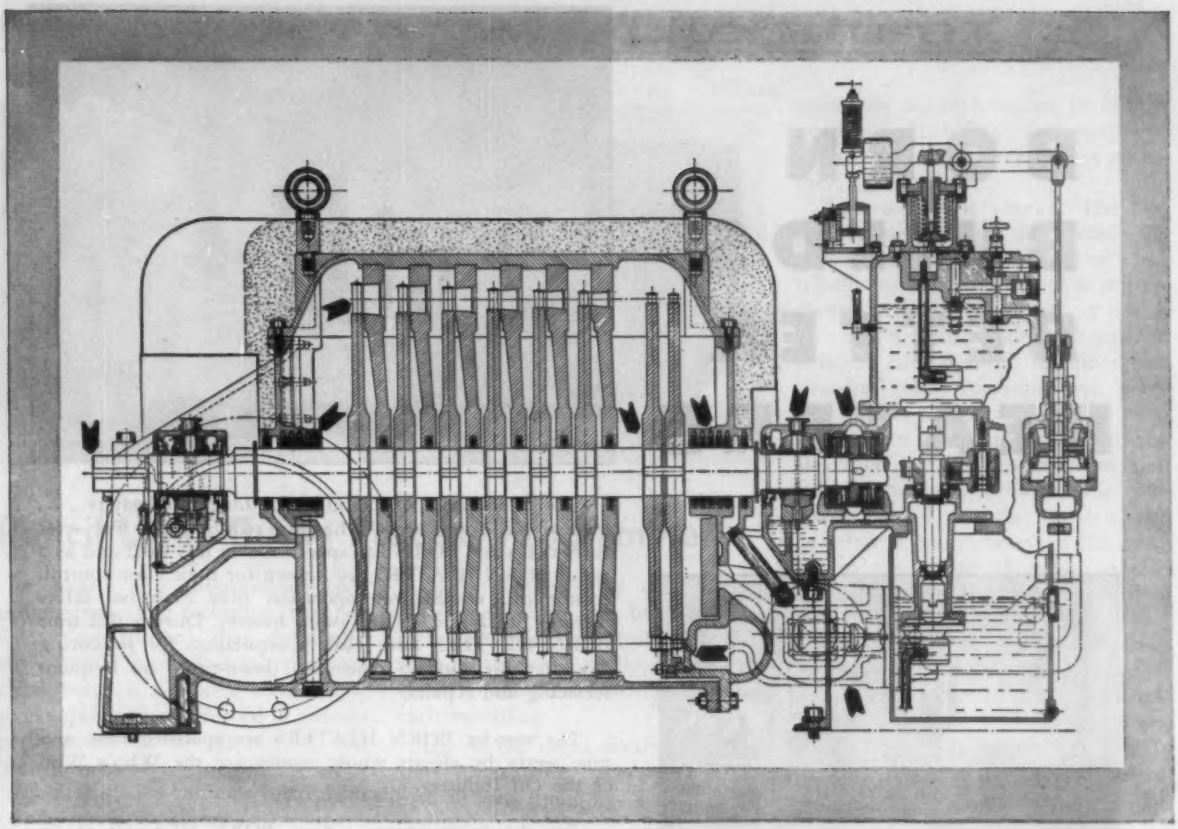
Sauereisen Cements Company — Pittsburgh 15, Penna.

When you see a large chimney think of Sauereisen Cements.



ANOTHER INSIDE STORY OF THE UNIVERSAL ACCEPTANCE OF MURRAY MULTI-STAGE TURBINES IN THE MECHANICAL DRIVE FIELD

- Husky accurately machined shaft.
- Discs shrunk and keyed in place.
- Stainless steel nozzles and blading throughout.
- Spherical seated sleeve bearings.
- Kingsbury thrust bearing.
- Center line support.
- Carbon ring gland seals.
- Double seated balanced governor valve — stellited.
- Choice of speed governors from simple mechanical type to precision oil relay.
- Bolt type overspeed trip governor.
- Steam conditions to 600 PSIG and 750°F.
- Condensing or non-condensing.

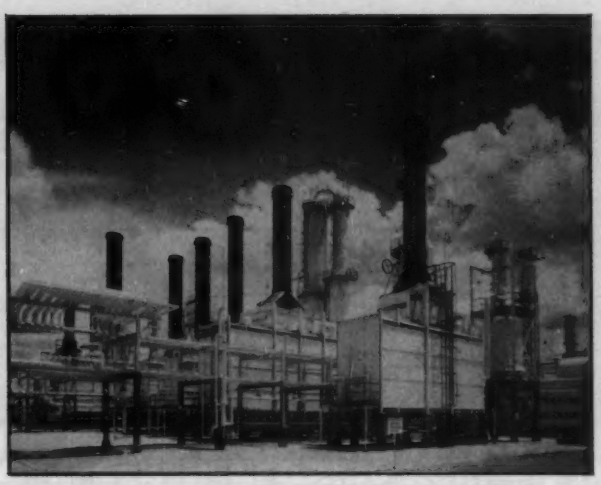
Our nearest representative will gladly help you solve your mechanical drive turbine requirements. Just write to Murray Iron Works Company, Burlington, Iowa, for his name.

Murray
TURBINES

MURRAY IRON WORKS COMPANY • BURLINGTON, IOWA
Builders of Steam Power Equipment for Nearly a Century

For more data on advertised products, use Readers' Service Cards, last page.

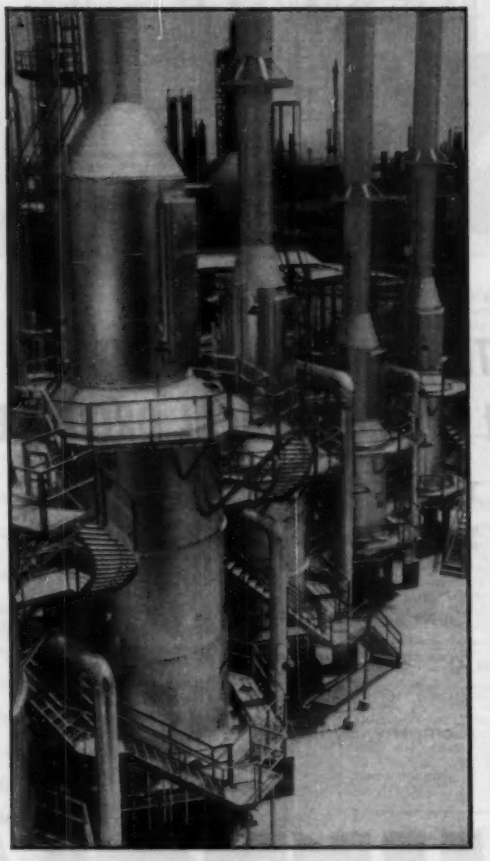
BORN BUILDS BETTER HEATERS



For one thing BORN builds nothing but heaters . . . heaters for every process heating requirement. For over forty-two years BORN has specialized in this field and as a result BORN HEATERS are known for their close control, economical, trouble-free operation plus exclusive safety features not found on any other heaters. During this time BORN HEATERS have built a reputation for producing day after day with no expensive "down-time" for frequent servicing and repairs.

No wonder BORN HEATERS are specified time and time again by clients whose names are the Who's Who of the Oil Industry.

For the complete story on a BORN HEATER to fit your needs, write, wire or call your BORN representative. He's anxious to serve you.



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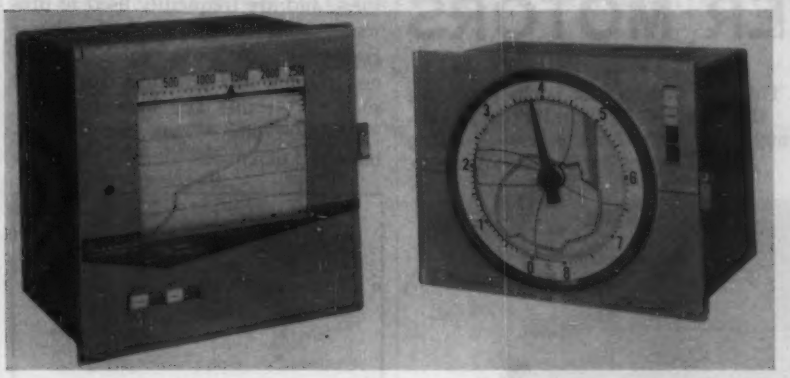
BORN Engineering Company
Manufacturers of Direct-Fired "UPFLO" Heaters
TULSA, OKLAHOMA

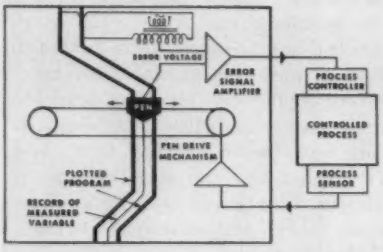
New Equipment & Literature...



Pencil Lines Guide Process Programmer

A totally new programming-controlling-indicating-recording instrument (see photo) that simultaneously "reads" a pencil-drawn program chart, controls a process accordingly, then superimposes a record of process performance on the same chart, has been developed.

At first glance the new instrument (trade name Prekorder) looks much like conventional circular and strip-chart recorders. The only visible hint that this instrument is a distinct departure from conventional types is the absence of all cams, cam followers, and function generators, heretofore essential components of a process programmer. Instead, the program appears as a double-line graph, which you pencil directly on the recording chart. The controller, sensing any deviation of the recording pen from the middle of the pencilled graph regulates the process to oppose the deviation. Significant cost savings are attributed to the elimination of the cam mechanism and related circuits.



Since the recording pen-probe senses its position between the program chart lines without ever touching them, the master program chart may be overlayed by clear vellum paper on which the ink record is made. The master program chart may then be used repeatedly, as only the vellum overlay need be changed after each recording.

Use of the chart overlay also permits introducing variable programmed process limits by merely pencilling boundary lines on the overlay. If the process deviates so far from its program that the recording pen contacts one of these lines, a relay energizes a warning signal or a process shut-down system.

Control system gain (sensitivity) may be programmed along with the controlled parameter by merely varying the spacing between the plotted program chart lines. Thus, the line spacing may be widened to reduce sensitivity during program periods of possible instability, and narrowed again where tighter control is necessary.

Here is how it works. The two parallel pencil lines that define the process program are connected electrically to the two ends of a center-tapped transformer winding which serves as a voltage source for an electrostatic field between the lines (see drawing). The recording pen, serving also as a capacitive probe, picks up an error signal proportional to any deviation of the pen from its null position midway between the program lines. This error signal is used to effect a readjustment of the process in the proper direction to ultimately recenter the process recording pen.

The system of programming-controlling-indicating-recording is usable wherever conventional chart recorders are used, as it is adaptable to any process which may be electrically controlled and which can be monitored by a transducer either mechanically or electrically connected to the recording pen. Typical examples are in the programming and control of temperature, pressure, voltage, power, liquid level, humidity, flow, pH, position, speed, force, etc. Prekorders are presently offered in both circular and strip-chart types and with a broad range of scales, chart speeds, pen speeds, and auxiliary control functions. Research, Inc.

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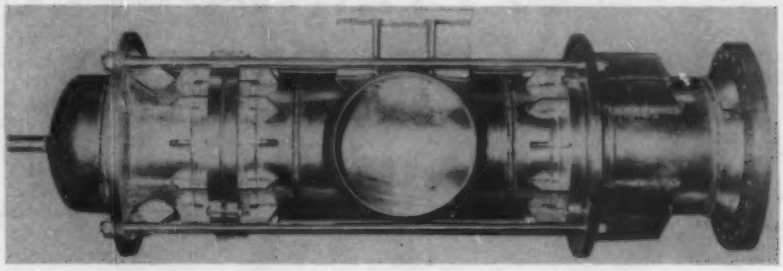


Pressure-Balanced Joints Absorb Thrust

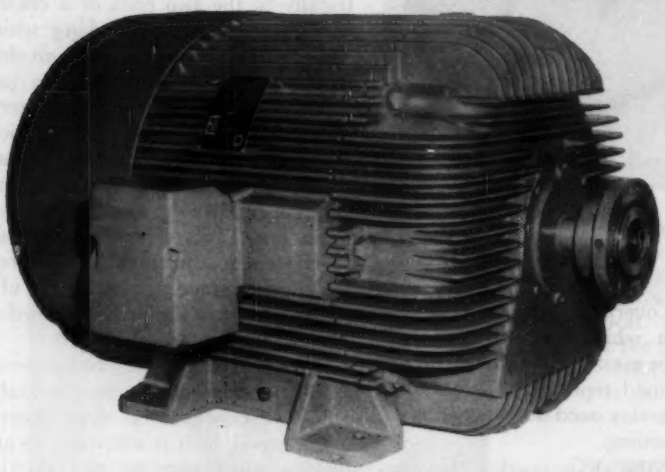
A complete line of pressure-balanced expansion joints for absorbing pipeline movement without imposing pressure thrust has been announced.

Installed at elbows or points where piping changes direction, the pressure-balanced expansion joints use a counterbalancing outer bellows to absorb line pressure where anchoring is not practical.

The expansion joints have application in chemical plants, refineries, oil

ELLIOTT C-W SEALEDPOWER MOTORS

This new 300-hp unit is the largest of the Elliott C-W "family" of ribbed-frame enclosed motors, pioneered in the United States by Crocker-Wheeler.



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IMPORTANT FACTS are given in new Elliott Bulletin PB 6000-2. Send for free copy now.

ELLIOTT Company

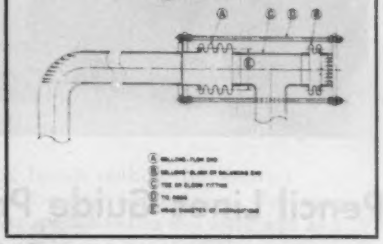
W9-C Crocker-Wheeler Plant • Jeannette, Pa.

Equipment . . .

and gas lines, power plants, steam lines, and are frequently used to protect turbine housings and exhaust connections, stage bleeders, condensers, pumps and rotating equipment such as turbines and blowers.

Figure 2 shows how the pressure-balanced expansion joints work. Pressure in the expansion joint A surges the elbow at left and against the closed end of the balancing expansion joint B. Thus, force exerted by internal pressure against the line is balanced by an equal and opposite force, transmitted to the line through the tie rods from the blanked end of the balancing expansion joint.

Figure 2



The expansion joints are available in diameters from 3 inches to 50 feet for temperatures from —320 F to 1,600 F and pressures up to 2,500 psi. Special units are available for more severe conditions. They are available in a variety of bellows: non-equalizing type, self-equalizing type, and HyPTor type. The HyPTor type is also used for lower pressure applications where temperatures are high. Zellea Brothers.

Circle E2 green card, last page

Bridge Decking Information Available in New Brochure

A new catalog brochure is available giving information on flowdeck bridge decking currently available for heavy duty applications. Fisher & Ludlow, Ltd.

Circle E3 green card, last page

Teflon Hose Inert To All Industrial Chemicals

Fluoroflex-T (teflon) transfer hose, inert to all acids and industrial chemicals, has now been developed.

The abrasion resistant rubber jacket is reinforced with a spiraled high tensile wire to prevent crush or collapse. A layer of teflon is carried through the hose and over the face of the flange. Fluids being transferred cannot come in contact with, or be contaminated by, the metal flange fittings or outer covering. The non-adhesive surface of the Teflon permits rapid flow of

COMPRESSOR QUIZ

Take this 5 minute quiz and check your knowledge of balanced opposed compressors.... ANSWERS ON NEXT PAGE. NO PEEKING!

1. What is the reason for an outboard bearing supported motor?

- ☐ Accessibility
- ☐ Shaft alignment
- ☐ Weight saving

2. Which design provides the smallest force couples?

- ☐ Bearing between the crank throws
- ☐ No bearing between the crank throws
- ☐ Both are equal

3. Structurally, what's the critical point in the multi-crank horizontal compressor from a design viewpoint?

- ☐ Lateral forces in the frame
- ☐ Vertical forces in the frame
- ☐ Cylinders

4. What type of motor is usually used on a balanced opposed compressor?

- ☐ Induction
- ☐ Engine-type synchronous
- ☐ Wound rotor

5. Can machine-mounted coolers and interstage piping be factory pre-fitted?

- ☐ Yes
- ☐ No
- ☐ Only on simple arrangements

6. Why is the balanced opposed compressor easier to install than other types of equivalent size?

- ☐ Lighter weight
- ☐ Less parts
- ☐ Semi-packaged design

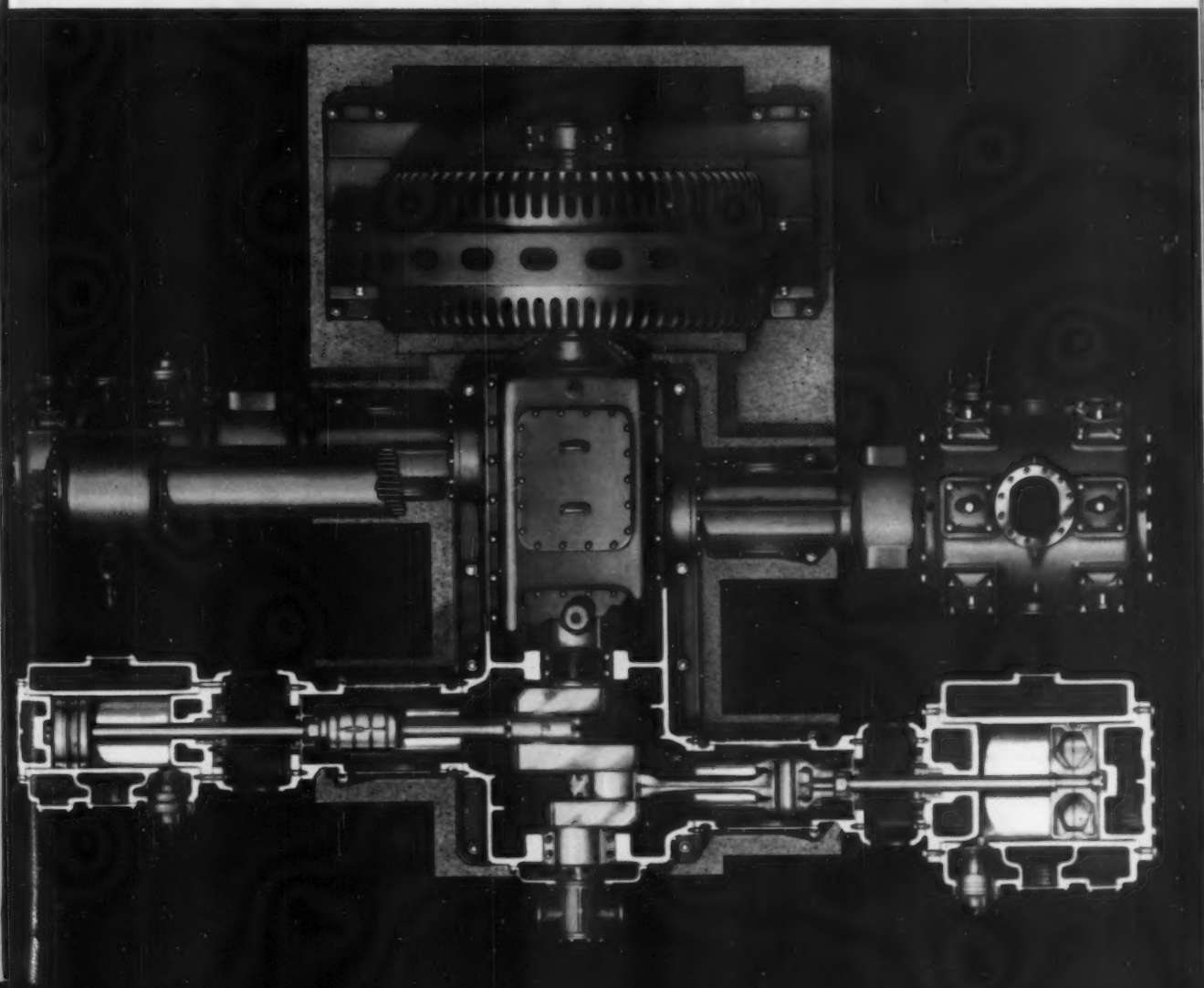
7. Is it common practice to install more than one compressor service on a single multi-cylinder frame?

- ☐ Yes
- ☐ No

8. Industry's most preferred compressor valve is standard with Worthington. It is:

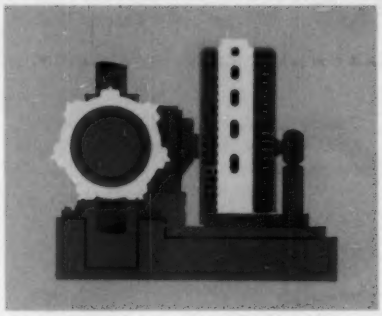
- ☐ A plate valve
- ☐ A spring activated valve
- ☐ A Feather Valve

WORTHINGTON



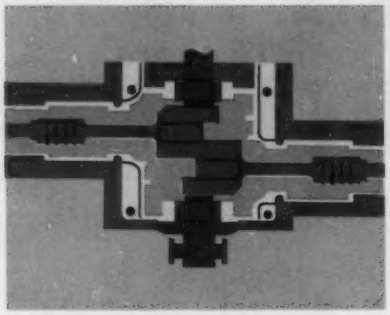
ANSWERS

to key compressor questions on previous page



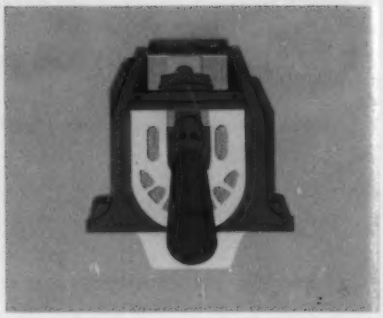
1. What is the reason for an outboard bearing supported motor?

Ans: Shaft alignment. Secure and permanent support of the large synchronous motor rotor is best obtained by placing a bearing on each side of the rotor.



2. Which design provides the smallest force couples?

Ans: No bearing between the throws. Worthington's adjacent crank design reduces couple arm to a minimum.

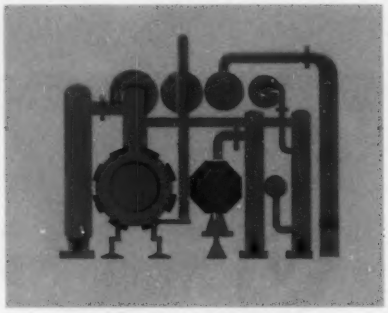


3. Structurally, what's the critical point in the multi-crank horizontal compressor from a design viewpoint?

Ans: Lateral forces in the frame which tend to distort the frame. Worthington's precision machined and fitted tie bars give solid support to the frame, preventing misalignment due to distortion.

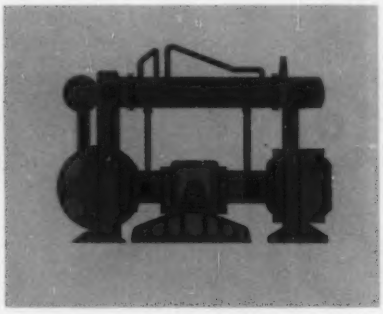
4. What type of motor is usually used on a balanced opposed compressor?

Ans: Engine-type synchronous is the major application; but complete flexibility of Worthington design permits use of any type driver, including turbine and gear or power engine.



5. Can machine mounted coolers and interstage piping be factory pre-fitted?

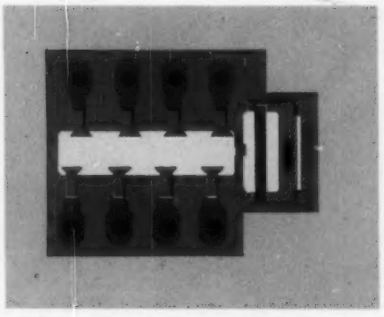
Ans: Yes. In fact, when overhead mounted piping and coolers are furnished by Worthington, such piping and coolers are always completely assembled and fitted to the compressor before it leaves the factory.



6. Why is the balanced opposed compressor easier to install than other types of equivalent size?

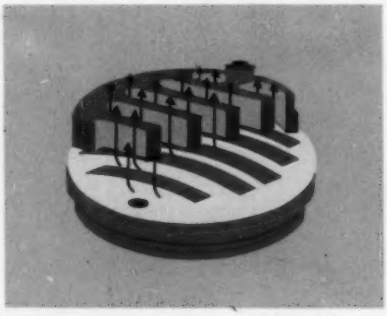
Ans: Semi-packaged design. Self aligning features permit easy and sure crankshaft, frame, and motor alignment on simplified foundation. Pre-fitted coolers and piping eliminate many problems associated with multi-stage compressor installation.

SCORING: If you got 7 or 8 questions right you're up-to-date on balanced opposed compressors and you recognize the value of the Worthington machine. If you got 5 or 6 right you're acquainted with some of the benefits of Worthington equipment, but you need brushing up. If you got less than 5 right, get in touch with your nearest Worthington technical representative. He'll give you the full story on the many advantages of the Worthington design. Worthington Corporation, Harrison, N. J. In Canada: Worthington (Canada) Ltd., Brantford, Ont. 36.5



7. Is it common practice to install more than one compressor service on a single multi-cylinder frame?

Ans: Yes. Particularly where the compression services are related, as in chemical plants. The arrangement results in substantial savings in initial plant cost.



8. Industry's most preferred compressor valve is standard with Worthington. It is:

Ans: Feather Valve! By actual count of 2 to 1, this outstanding compressor valve is preferred by operators and engineers.

WORTHINGTON

Equipment . . .

fluids with little or no buildup of corrosive solids. This hose, easily cleaned by a simple flushing operation, allows rapid conversion from one material to another. The non-aging characteristic of teflon also insures long service life.

Current production of the chemical transfer hose for loading and unloading operations or emergency piping systems is in 1½, 2 and 3 inch diameters to specified lengths. Larger diameters will be available shortly. Resistoflex Corp.

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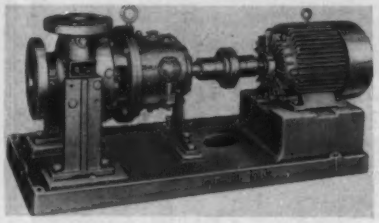

Centrifugal Pump Meets API Specification 610

Two new process pumps, Figure 3675 and Figure 3775 designed specifically for the petroleum processing industry are described in Bulletin 724-1.

The Figure 3775 frame-mounted centrifugal pump is built in accordance with API 610 specifications and is available in 11 sizes with capacities up to 850 gpm, heads up to 350 feet, and a maximum operating temperature of 600° F. The Figure 3675 is a close-coupled version of the Figure 3775 with the pump end bolted directly to a flange faced motor, and the rotating pump parts assembled on the motor shaft extension. It is available in 11 sizes with capacities up to 850 gpm, heads to 350 feet, and a maximum operating temperature of 275°F. Specifications, photographs, dimensional drawings and construction data are included in the bulletin. Goulds Pumps, Inc.

Circle E5 green card, last page

Braided Steel Wire Gives Burst Protection In Hoses

Steam cleaning and flash-fire protection in refineries is made safer with #200 BW Steam Hose, featuring braided steel wire burst protection. Designed for use to 200 pounds saturated steam pressure at 388 F, steel wire braid construction gives unusual strength and flexibility, assures maxmum safety. Virtually burst-proof because wire braid prevents open burst when worn out. Static conductors make for utmost safety in refineries.

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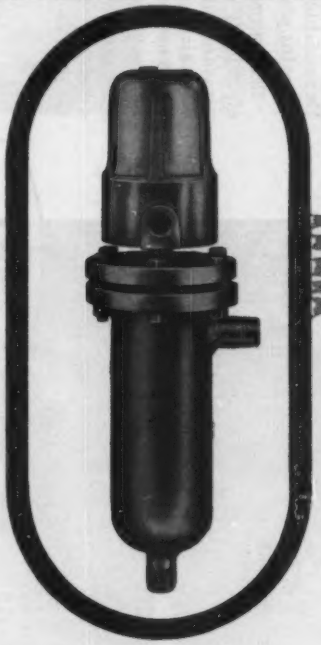

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For more data on advertised products, use Readers' Service Cards, last page.

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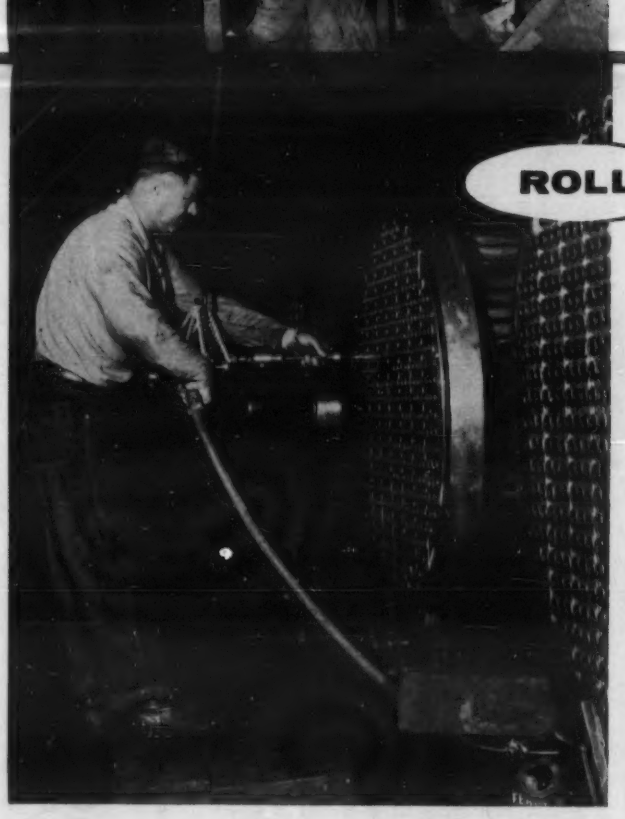
FARROWTEST, an eddy-current nondestructive test, is offered as an alternative to other less positive tests. To get the facts first-hand, call your Republic representative. Or send coupon today.

FARROWTEST REJECT TABLE

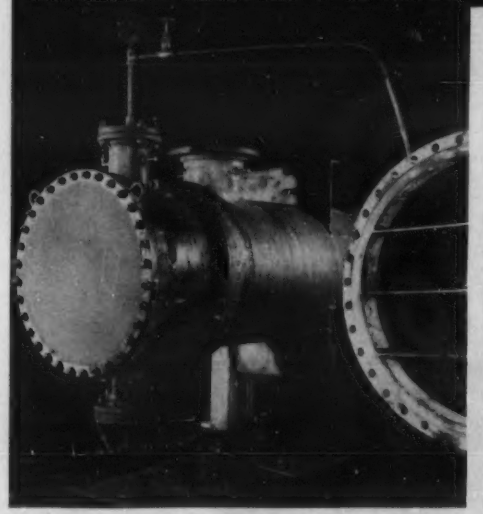
Wall Thickness (B.W. Gage)	Minor dimension of the defect (Length or Depth)	Defective Area (Length, Depth Plane)
20	.006"	.0025 sq. inches
18	.006"	.003 sq. inches
16	12½% of wall	.003 sq. inches
14 and 13	12½% of wall	.004 sq. inches
12 and heavier	12½% of wall	.005 sq. inches

FARROWTEST detects and rejects not only tubing containing defects which completely penetrate the wall; but also tubing with defects equal to, or greater than, those shown in this table. For irregular defect shapes, a tube with defect area equal to or greater than shown above is rejectable. Where required, sensitivity of FARROWTEST equipment can be calibrated to reject defects of lesser specified area than shown in table, at extra cost.

REPUBLIC SERVES THE PETROLEUM PROCESSING INDUSTRIES



REPUBLIC SERVES THE PETROLEUM PROCESSING INDUSTRIES



REPUBLIC ALLOY STUDS AND HIGH CARBON HEX NUTS go hand in hand in serving the petroleum processing industries. They withstand major stress imposed on a wide variety of equipment. Clean accurate threads provide high strength and wear resistance, plus ease of assembly and disassembly required where equipment maintenance calls for it. Republic has fasteners to meet every application. Send coupon today.

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☐ FARROWTEST ☐ Republic Containers

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For more data on advertised products, use Readers' Service Cards, last page.

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Equipment . . .

an asbestos covered innertube of thick heat resisting rubber—Special Butyl cover for maximum heat and weather resistance. Minimum elongation and contraction under pressure, and longer hose life are also claimed for this construction. Raybestos-Manhattan, Inc.

Circle E6 green card, last page

Inhibitors Featured In Gasoline Additive Booklet

Tenamene petroleum inhibitors are featured in a new booklet on gasoline additives just published.

The Tenamene inhibitors, which include three different gasoline antioxidants and two metal deactivator formulations, are described as to chemical structure, properties, and function. Suggestions are given as to the proper selection of an inhibitor, along with storage stability data on various inhibited gasoline stocks. Eastman Chemical Products, Inc.

Circle E7 green card, last page

Pressure Sealing Gate Valve Needs No Lubrication

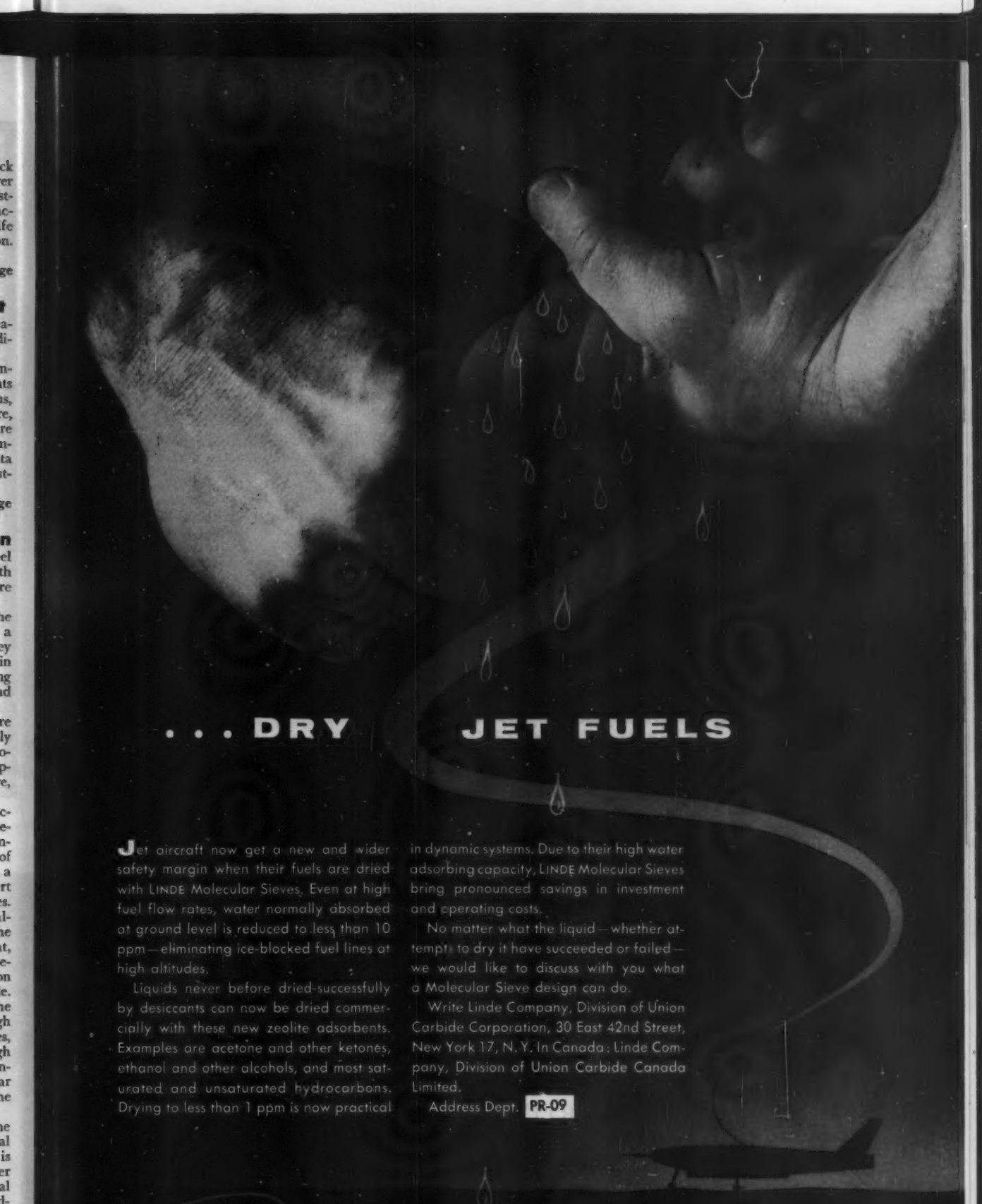
A new line of pressure-sealing steel gate valves that provide a tight seal both upstream and downstream and require no lubrication has been introduced.

The new valve line is available in the ASA 150 and 300-pound classes in a range of sizes from 2 to 30 inches. They were designed for a variety of uses in the chemical and petroleum processing operations, primarily on processing and service lines.

The new valve incorporates a full bore and through conduit, seats that are fully protected from flow and lading and automatically adjust for wear, automatic upstream relief for excessive body pressure, and ease of maintenance.

An unusual feature of the valves, according to the manufacturer, is the design of the floating seats. Each seat consists of two kinds of rubber, molded to a hardened steel insert ringed with holes. Soft rubber, for sealing, is applied to the back of each seat, and tough, abrasive-resistant rubber on the front or gate side. Pressure forces the soft rubber through the metal insert holes, reinforcing the tough rubber and compensating for any wear on the face of the seat.

The seats provide a double seal. The tough rubber creates a primary seal against the gate, and as line pressure is increased the gate compresses the rubber ring until the gate rests against the metal insert, providing a metal-to-metal secondary seal. This action forces the soft rubber on the back of the seat into its recess and prevents any downstream flow. The upstream seal is caused by line pressure forcing its way into the seat recess behind the upstream seat moving the seat



. . . DRY JET FUELS

Jet aircraft now get a new and wider safety margin when their fuels are dried with LINDE Molecular Sieves. Even at high fuel flow rates, water normally absorbed at ground level is reduced to less than 10 ppm—eliminating ice-blocked fuel lines at high altitudes.

Liquids never before dried-successfully by desiccants can now be dried commercially with these new zeolite adsorbents. Examples are acetone and other ketones, ethanol and other alcohols, and most saturated and unsaturated hydrocarbons. Drying to less than 1 ppm is now practical in dynamic systems. Due to their high water adsorbing capacity, LINDE Molecular Sieves bring pronounced savings in investment and operating costs.

No matter what the liquid—whether attempts to dry it have succeeded or failed—we would like to discuss with you what a Molecular Sieve design can do.

Write Linde Company, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y. In Canada: Linde Company, Division of Union Carbide Canada Limited.

Address Dept. **PR-09**

Linde MOLECULAR SIEVES

UNION CARBIDE

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PEABODY FLEXIPRO BURNER

for firing oil and gas separately or SIMULTANEOUSLY

The Peabody Flexipro (flexible process) refinery burner is a natural draft burner for vertical or horizontal firing. It is short, compact, readily accessible, and has a simple rugged dual air register.

The Flexipro burner features:

- **Readily removable fuel units**
- **Maximum availability**
- **Low maintenance**
- **Positive air flow control**
- **High firing efficiency**
- **Excellent stability at adverse fuel-air ratios**

It is suitable for capacities from 2,000,000 to 16,000,000 B.T.U./hr.

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Equipment . . .

tightly against the gate, but still sealed from the body cavity.

A neoprene rubber-bellows indicator, colored bright yellow for long-range visibility, extends above the handwheel when the valve is open and retracts into the handwheel when the valve is closed. It also protects the stem threads from dirt and corrosion.

The body and bonnet are cast steel and the stem is heat-treated, hardened steel. The gate is made of steel, hard chrome-plated for protection against wear and corrosion. W-K-M Div. of ACF Industries, Inc.

Circle E8 green card, last page

Oscillograph Shows Merits Of Oil-Immersed Contactor

Rated at 400 amp, 5 kv, 50 mva in a small tank which can be mounted in the new small size front access starter, the oil-immersed AC contactor unit is designed for operation in hazardous, corrosive or dusty atmospheres. It will handle 2,500-hp squirrel cage motors at 4,800 volts, and unity-power synchronous motors up to 3,000 hp, 4,800 volts.

The contactor is 20 inches deep, 29 inches wide and 32 inches high over the bushings. It mounts readily on the back wall of a cubicle and has a self-contained tank lowering device. It weighs 270 pounds less oil and is equipped with an oil-level sight-gauge drain and fill plugs.

Through the use of oscillograph reproductions, the performance merits of the contactor are authenticated in a new bulletin just released. Allis-Chalmers Mfg. Co.

Circle E9 green card, last page

Bulletin Describes Stainless Steel Welding Fittings

A new brochure identified as #P6 gives information on a line of cast stainless steel flanges and welding fittings including bends, tees, reducer caps and reducing bends—also weldneck flanges and slip-on flanges in stainless cast steel. A. P. V. Paramount, Ltd.

Circle E10 green card, last page

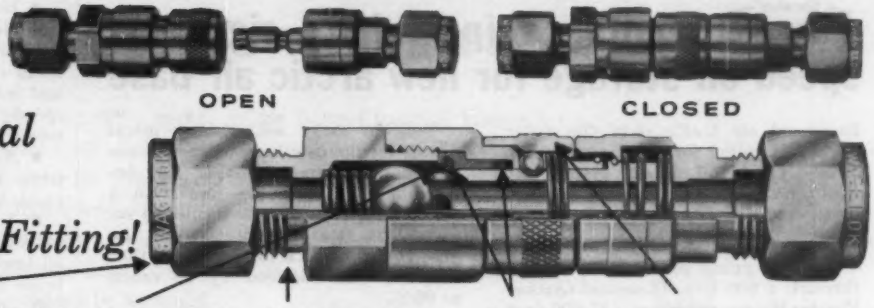
Service Requirements For Metal Packings In Booklet

A new bulletin dealing with the subject of metal packings for pumps, engines and compressors, has just been published. The 24-page booklet contains comprehensive data for correct selection, application and installation of metal packing and it is complete with explanatory illustrations.

The bulletin is designed specifically to acquaint users with pressure temperature and other service requirements relative to the various kinds of metal packing currently available. To this end, the bulletin is divided into six subdivisions. The first section describes free-floating metal packing, taking in detail the annular solid-cup type, high pressure packing and the split-case multi-groove type. Next in order are subdivisions on metal rod packing rings, metal scraper rings, metallic or non-floating packing and piston rings.

Swagelok Quick-Connect Fitting Installation in Boeing Airplane Company, Seattle, Wash., Test Facilities for Boeing 707 Jet Stratoliner.

Here's the secret of this fast, positive-seal Swagelok Quick-Connect Fitting!



1. Swagelok Quick-Connects with single end or double end shut off for tube to pipe, tube to tube, bulkhead tube to tube applications are available in brass and stainless steel in sizes for ¼" and ⅜" O. D. tubing.

2. Flow resumed instantly and vacuum tight seal assured when connection is made.

3. Light, compact, streamlined design. Occupies little space. For use with portable equipment, and bulkhead or panel applications.

4. Instant-acting seals completely prevent loss of pressure when fitting is disconnected.

5. No twisting, turning or wrench action necessary. Easy straight-line finger tip pull or push action for instant connecting or disconnecting.

In the Boeing Airplane Company photo shown above, the tubes are instrumentation pressure lines running from the large jet engines on test stands to the patch board, where the lines are coupled into measuring devices.

The Boeing Airplane Company adopted this positive Swagelok Quick-Connect Fitting to simplify test installations, and substantially cut down test set-up time. Both ends of the many pressure lines are Swagelok-equipped. Previously, engineers used a screw-type fitting which required a wrench and valuable time-consuming operations to tighten and remove.

Swagelok engineers are equipped with experience, ability, and a wide range of tube fittings designed to meet your individual problems. Quick delivery of Swagelok tube fittings from local distributor stocks.

Swagelok® TUBE FITTINGS

CRAWFORD FITTING COMPANY
884 East 140th Street, Cleveland 10, Ohio
Crawford Fittings (Canada) Ltd., Niagara Falls, Canada

600-foot length of Thermoid-Quaker hose, self-propelled both off and on the reel, floated on inflatable rubber "sausages."

Quaker Thermoid floating ship-to-shore rig helps speed oil storage for new arctic air base

Increased air traffic over the polar route has called for an immense new airfield and oil-piping system at Frobisher Bay, Baffin Island, just completed by Foundation Company of Canada Limited.

Tankers pump petroleum products through a 600-foot Thermoid-Quaker Floater Hose assembly to a 15,000-foot pipeline feeding the huge tank farm at Frobisher. An 8" Thermoid-Quaker discharge hose is floated on special inflatable Thermoid-Quaker pontoons and reeled on a power winch. This three-part rig makes up the complete Thermoid-Quaker assembly.

You do away with bulky metal drums for floating hose when you use this new Thermoid-Quaker rig. Inflatable floats take up less than a quarter of the space formerly required by floating drums. And the hose comes in such long sections that couplings are reduced by as much as 90%.

If you load or unload tankers off-shore, investigate the Thermoid-Quaker Floater Hose combinati n. Ask the Thermoid distributor, or write *Thermoid Division, H. K. Porter Company, Inc., Tacony & Comly Sts., Philadelphia 24, Pa.*

THERMOID PORTER DIVISION

H.K. PORTER COMPANY, INC.

PORTER SERVES INDUSTRY: with Rubber and Friction Products—THERMOID DIVISION; Electrical Equipment—DELTA-STAR ELECTRIC DIVISION, NATIONAL ELECTRIC DIVISION; Specialty Alloys—RIVERSIDE-ALLOY METAL DIVISION; Refractories—REFRACTORIES DIVISION; Electric Furnace Steel—CONNORS STEEL DIVISION, VULCAN-KIDD STEEL DIVISION; Fabricated Products—DISSTON DIVISION, FORGE AND FITTINGS DIVISION, LESCHEN WIRE ROPE DIVISION, MOULDINGS DIVISION, H. K. PORTER COMPANY de MEXICO, S. A.; and in Canada, Refractories, "Disston" Tools, "Federal" Wires and Cables, "Nepcoduct" Systems—H. K. PORTER COMPANY (CANADA) LTD.

Equipment . . .

The final section of the booklet discusses testing and service facilities available at Garlock to assist users in selecting and maintaining metal packing. The Garlock Packing Co.

Circle E11 green card, last page

New Cargo Crane Features Diversified Design

A new cargo crane has been developed which can lift 5 tons at 80 feet radius or 6 tons at 70 feet radius, the latter with its shorter jib being no heavier than the manufacturer's previous model. To change from one type to the other it is only necessary to replace the jib and apex and alter the hoist motor speed. The crane can be adapted for occasional grabbing duties.

A specially developed, simplified, Ward-Leonard set drives the hoist winch through double helical and spur gearing. It has an exciter, energized by the current in the armature loop circuit, which simultaneously controls the winch motor field and the generator field. This provides the following main advantages:

- Hoisting and lowering speeds are variable and controlled by the driver.
- Light loads can be hoisted at three times the speed of the maximum load, and intermediate loads at corresponding speeds, without the use of discriminating relays.
- A similar characteristic is available when lowering, i.e., as the load is increased the maximum speed is decreased.
- Automatically controlled lowering by regenerative braking is employed on all lowering notches. An electro-magnetic brake is used only to hold the load in the "off" position and for an emergency.
- Control is obtained entirely on light current contactors. No contactors are used in the main DC circuit.
- Whatever the load no heavy current surges are thrown on the supply line.

The unit offers a number of other advantages including flexible control and reduced maintenance. Stothert & Pitt, Ltd.

Circle E12 green card, last page

Flier Tells About Low Cost Way To Create Vacuum

If you are looking for a low cost way to create vacuum, increase pressure or mix gases, you will be interested in obtaining a copy of a new 4-page flier which describes the company's Series M general utility ejectors. This new line of ejectors can be used to handle either wet or dry mixtures as well as those contain-

RING OF STEEL

Defies Pressure Times Ten

The Flexitallic gasket in the bonnet joint of Hancock Steel Gate Valves cannot blow out even if pressures exceed ten times the rating of the valve. Valve maintenance and equipment down-time are greatly reduced. Made of a spiral-wound ribbon of stainless steel with asbestos filler, the gasket has spring-like compressibility — cannot be flattened.

Only the specially-designed Hancock bonnet joint with built-in compression limit can make full use of the positive sealing power of this ring of steel. Such advanced valve engineering is one example of total Hancock quality that assures trouble-free performance. Your nearby industrial supply distributor will gladly explain every economy feature of Hancock Steel Gate Valves. Phone him today.

Hancock 800# Steel Gate Valve, Type 950. Sizes: ¼" thru 2".

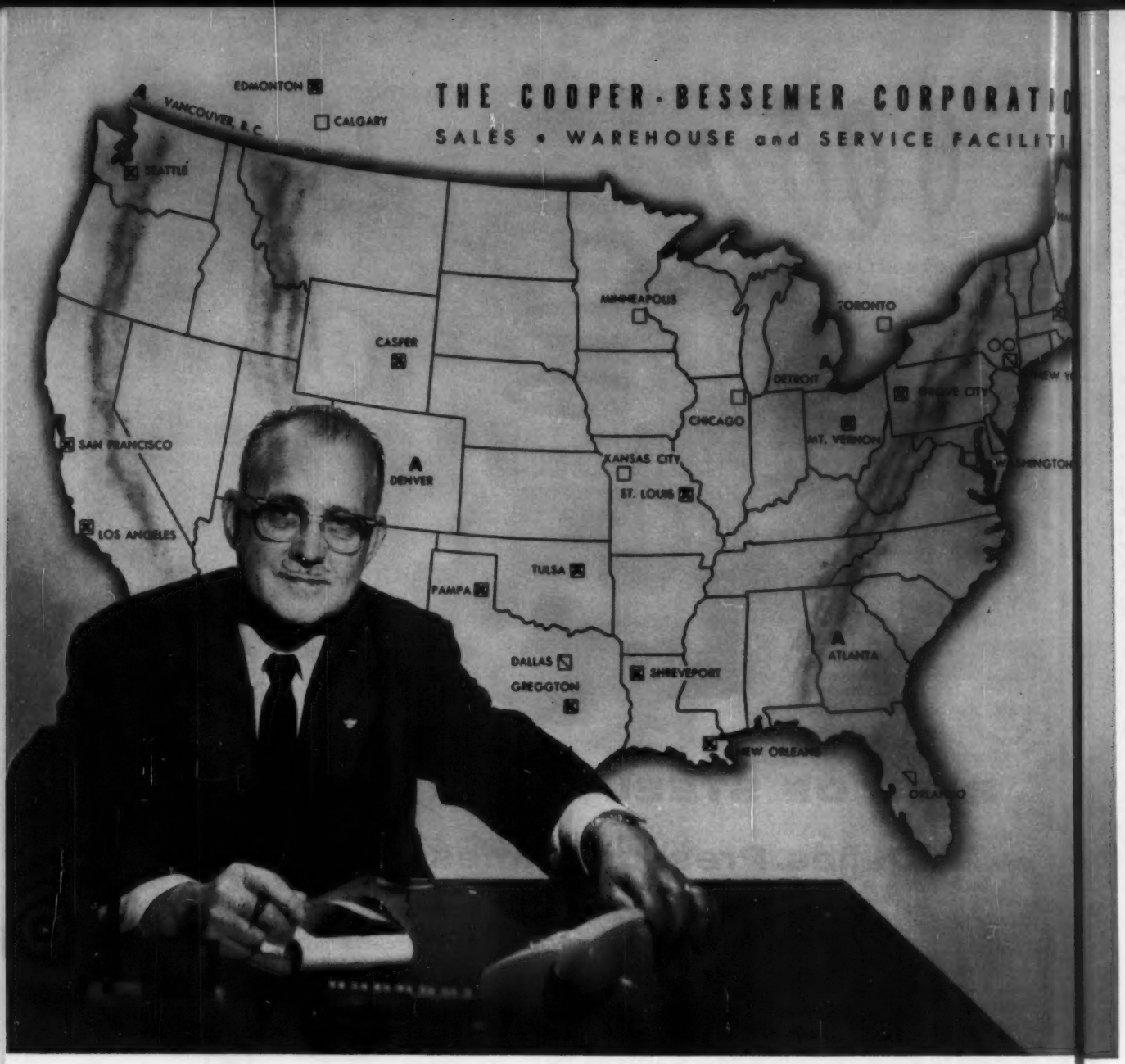
HANCOCK STEEL VALVES

A product of

MANNING, MAXWELL & MOORE, INC.

Consolidated Ashcroft Hancock Division • Watertown, Massachusetts
In Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario

For more data on advertised products, use Readers' Service Cards, last page.



Edmund S. Budd, *Manager of Parts Division,*
The Cooper-Bessemer Corporation, points out that...

You are this near to Cooper-Bessemer service!

Cooper-Bessemer engineers are ready to assist you in planning power or compression facilities, or solving operating problems.

Experienced Cooper-Bessemer field technicians assist you in installation and servicing of equipment.

Cooper-Bessemer warehouses, strategically located, provide replacement parts for speedy servicing and peak availability of your facilities.

WHEN YOU INVEST in Cooper-Bessemer engines, compressors or controls, our service facilities are as close to you as the telephone... night and day! We serve you in these three important ways:

Technician service. Our skilled installation and maintenance crews are permanently located in areas throughout the country, ready to assist you, to assure top economy of operation and availability of your Cooper-Bessemer equipment.

Warehouse service. We maintain an extensive inventory of replacement parts for Cooper-Bessemer products in strategic locations to give prompt attention to your needs.

Engineering service. As new or changed conditions arise, our experienced field service engineers can give you on-the-spot recommendations. And they are backed up by the strong team of Cooper-Bessemer engine and compressor engineers in Mount Vernon.

The superiority of Cooper-Bessemer Service can save you thousands of dollars yearly in capital investment and in operating cost. Make sure you take this important *plus value* into account when you specify and buy engine and compressor facilities.

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ENGINES: GAS - DIESEL - GAS-DIESEL
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FOR CATALYST BED SUPPORT:

This Porter Mullite Pellet costs up to 50 per cent less!

Porter Mullite Pellets actually do cost up to 50 per cent less than most catalyst bed support materials now available. *And you make no operational sacrifice to gain this savings!*

Porter mullite pellets have been commercially tested for over three years, as inert support for active catalyst, in many major refineries. They've withstood all the trials of heat, shock and pressure without breaking or dusting. Porter mullite pellets have successfully resisted abrasion, erosion and crushing . . . completely protecting the valuable catalysts from contamination.

Convert to Porter mullite pellets now, and reflect these important cost-savings in your refining process. For complete information, write: *Refractories Division, H. K. Porter Company, Inc., Porter Building, Pittsburgh 19, Pennsylvania.*

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Equipment . . .

ing solid materials such as chaff or dust. Accidental entrainment of liquid will not damage the ejector.

Series M ejectors are designed to operate with steam or motive gas at 75 to 200 psig. They are available in 1½, 2, 3 and 4-inch suction sizes with a total of 16 different ejectors. Their design features simplify two-piece construction. There are no moving parts to wear out, lubricate, adjust or replace, and no expensive foundation is required. Ingersoll-Rand Co.

Circle E13 green card, last page

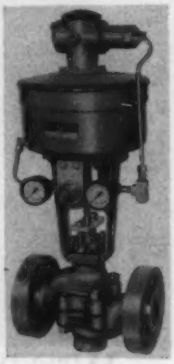
184-Page Floodlight Book Is Miniature Catalog

A new 184-page bulletin is a miniature edition of a popular floodlight catalog. Included in the pocket-sized book is all the original material: How to Select Floodlights, General Purpose Floodlights, Heavy-Duty Floodlights, Mercury Vapor Floodlights, Special Floodlights, Lighting for Hazardous Locations, Searchlights, Underwater Lighting, Floodlight Poles, Accessories, Installation Suggestions, and Lighting Calculations. Crouse-Hinds Co.

Circle E14 green card, last page

Control Valves Available With Ductile Iron Bodies

Control valves and handwheel valves with ductile iron bodies are now available.



Ductile iron (sometimes referred to as nodular iron) is a new cast metal which has the corrosion resistance of gray cast iron and ductility and strength approaching that of carbon steel. Ductile iron is lower in cost than steel or bronze and is a suitable replacement for both on many services where cast iron is not satisfactory. It has a higher temperature pressure rating than cast iron or bronze, and affords greater safety and is more rugged than cast iron due to its higher strength and ductility.

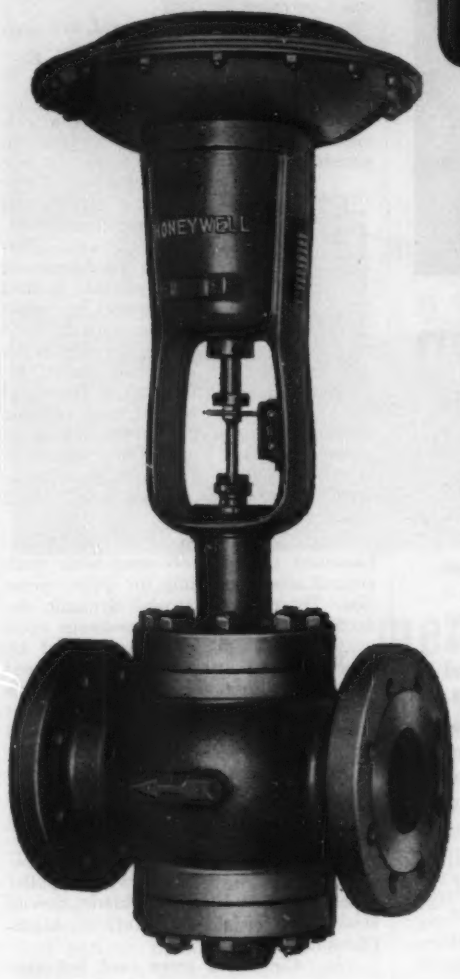
Series LB and LM ductile iron valves are available in the straight-through design in sizes ¾ through 6 inches, with 150-300# ASA raised-face integral flanges. All meet ISA face-to-face dimensions. Also available with screwed connections in sizes through 2 inches. Pressure-temperature ratings are in accordance with Part UCN of the ASME Boiler Code, Sec. VIII. Conoflow Corp.

Circle E15 green card, last page

Special Typewriter For Easier Computer Operation

Added convenience in computer operation has been made available through the introduction of a fully alphanumeric typewriter for the company's medium-

is your PROCESS FLOW CORROSIVE?



Honeywell control valves are available in a wide range of materials

Whether you're talking about corrosive or non-corrosive fluids, there's a Honeywell automatic control valve for your particular process flow. It is available in any castable body material and trim material such as . . . stainless steels, Hastelloy, Monel and Durimet 20. This variety of materials permits economical construction to fit your corrosive process flow application.

For corrosive or non-corrosive flows . . . or other process flow conditions . . . Honeywell valves are available in a wide range of types and sizes. When you need control valves . . . contact your local Honeywell field engineer. Write for new Catalog C800-1.

MINNEAPOLIS-HONEYWELL, Fort Washington, Pa.

Honeywell

H HONEYWELL *First in Control*

For more data on advertised products, use Readers' Service Cards, last page.

R-P&C Electric Furnace Iron

Better quality control of Iron Valve castings —through electric furnace melting

Castings manufactured from iron melted in electric furnaces have long been recognized for their superior qualities. The electric melting process permits a closer control of heat and chemical composition.

R-P&C's foundry produces electric furnace iron castings that meet the exacting requirements of good pressure castings. They provide a highly refined metal relatively free of impurities. Its dense grain structure gives it increased resistance to corrosion, high tensile and transverse strength, and excellent deflection characteristics. Physical requirements far exceed the standard requirements for valve castings.

Shown above is an R-P&C **Fig. 625 Gate Valve** of the flanged end type. It is available in sizes from 2" to 24". It can be supplied in bronze trim or all-iron construction. The R-P&C Iron Valve line includes other popular types of Gate, Globe, Angle and Swing Check Valves—manufactured of Electric Furnace Iron.

Your R-P&C distributor can supply you promptly with gate, globe, angle and check valves in bronze, electric furnace iron and cast steel, and forged steel; all in a wide range of sizes, styles and pressure classes. He also offers specialties such as Lubrotite gate valves, bar stock valves, asbestos packed cocks, cast steel fittings and pressure-seal cast steel valves. *See him or write...*

R-P&C VALVES ACCO

R-P&C Valve Division, American Chain & Cable Company, Inc.

Reading, Pa., Atlanta, Boston, Chicago, Denver, Detroit, Houston, New York, Philadelphia, Pittsburgh, San Francisco, Bridgeport, Conn.

Equipment . . .

scale G-15 digital computer. Data entering and leaving the computer via the typewriter can now be identified with alphabetic information and a variety of special symbols. Headings for columnar typeout, as well as complete format control, can be programmed.

All information is typed into the computer in the normal typing manner. Upper and lower case letters, numbers and special symbols are entered and typed out directly, without the necessity for manual encoding of alphabetic data, conversion subroutines or programmed carriage shifts.

The G-15 is now available with a choice of the alphanumeric typewriter or a standard numeric typewriter. Both units utilize a new base configuration which provides maximum reliability. Bendix Computer Div.

Circle E16 green card, last page

Wide Flexibility Featured In Turbine Agitator

Featuring flexibility in meeting a wide variety of process requirements from inventoried modular components, the Moduflex line of turbine agitators has been developed.

Five basic gear-drive configurations are available in sizes through 75 hp.: right angle head, belt driven, in-line with coupled motor, in-line with integral motor and variable speed. Each configuration is built in seven basic case sizes, with a choice of any AGMA gear ratio, and a choice of three mountings for open and closed tanks.

Gears in Moduflex drives are flame-hardened chrome-moly steel with teeth ground after hardening for quiet operation. To prevent harmful dynamic deflection, the shaft has a generous cross section and is rigidly supported by closely spaced spherical and tapered roller bearings. This design improves critical frequency to the point that standard Moduflex agitators can be used for most applications which formerly required steady bearings.

Lubrication of all moving parts in the gear case is provided by a positive oil pump. A dry-well seal prevents leakage.

In addition to choice of material for wetted parts, three standard impeller styles are offered: straight blade, curved blade, and 45 degree pitched blade. Chemineer, Inc.

Circle E17 green card, last page

Molecular Sieve Booklet Suggests New Applications

Since the introduction of molecular sieves to industry in 1954, all of the uses developed for these materials have depended upon their ability to *remove* substances from gases and liquids by selective adsorption. Recently, however, a new

Trainees using Rockwood Double Strength FOAM liquid learn one of the most effective fire-fighting techniques ever developed. Training cost is low because 3 gallons of FOAM provide 1,000 gallons of extinguisher.

Training men with Rockwood FOAM costs you least, saves you most

Rockwood Double Strength FOAM liquid gives you more efficient fire protection at lower cost than any other fire extinguishing agent. By mixing only 3 gallons of FOAM liquid with 97 gallons of water and 900 gallons of air you get 1,000 gallons of a powerful fire-fighting mixture — *the cost of which, per gallon, is only three tenths of 1% of the cost of FOAM.*

Double Strength FOAM liquid helps you improve and economize your departmental training too. The very small proportion required to produce this extinguishing agent permits training under actual fire conditions at negligible cost.

For further facts on Rockwood Double Strength FOAM, tested and listed by Underwriters' Laboratories, Inc., send coupon today.

ROCKWOOD SPRINKLER COMPANY
A Division of The Gamewell Company

Engineers Water... to Cut Fire Losses

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A Division of The Gamewell Company
Portable Fire Protection Division
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Please send me your illustrated booklet on Rockwood fire-fighting products.

Name _____

Title _____

Company _____

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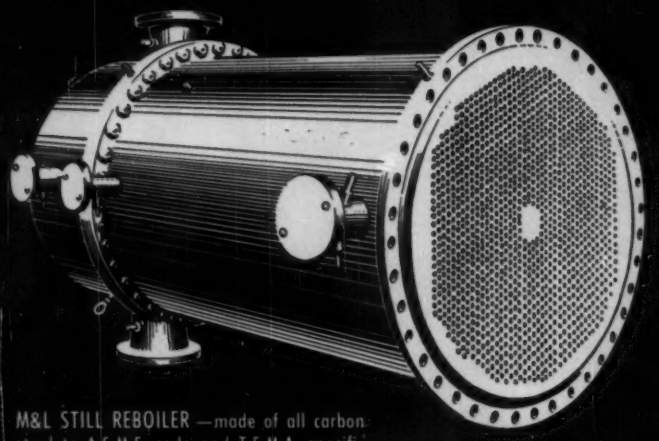
For more data on advertised products, use Readers' Service Cards, last page.

MANNING & LEWIS



M&L STILL REBOILER —made of all carbon steel to A.S.M.E. code and T.E.M.A. specifications. (Design temp. 450°F, weight 9500 lbs., Shell—44" dia., 8'9" length, 1-1/16" thick, 1500 steel tubes—¾" O.D. x 14 B.W.G.)

Many years of experience have given us an unusually thorough knowledge of the appropriateness, adaptability and qualities of fabrication of a wide variety of metals. This accumulated knowledge, coupled with our engineering experience and the important "extras" in fabrication, is your assurance of practical trouble-free equipment at the lowest possible cost.

It is impossible, in a field requiring such wide diversification, to illustrate, or even list all the products we have been called upon to supply. An excellent case in point, however, is the Reboiler above. In its fabrication, X-Raying was performed to assure perfect welds. This example is typical of the "extra" care you can expect and get from Manning & Lewis.

Call on us the next time you need equipment. We are fully qualified to design and fabricate to all codes.

M&L MANNING & LEWIS

ENGINEERING COMPANY

Dept. C, 28-42 Ogden Street, Newark, New Jersey

DESIGNERS & MANUFACTURERS OF QUALITY HEAT EXCHANGE EQUIPMENT

Equipment . .

and entirely different use for these imagination-catching products was announced. Molecular sieves were found to be useful for both *storing* and *taming* a large number of chemical compounds which are too volatile or too reactive to be useful for many applications. As you can easily imagine, the applications for such a material are legion. A booklet is available which will stimulate your imagination to conjure up new ways of using these materials.

The first chemical-loaded molecular sieves made available in commercial quantities were introduced by Linde Co. in 1958. The five standard products contained catalysts as accelerators for use in rubber and plastics formulations to prevent premature curing during processing. The catalyst is stored in the dry molecular sieve powder blended into the rubber stock until desorbed by heating to curing temperature. Linde Co.

Circle E18 green card, last page

No Exchanger Tube Damage Even When Tied in Knots

Although it will never have to suffer such contortions when used in heat exchangers, a new welded steel tubing can literally be tied in a knot without damage.

This new tubing line, designed specially for petrochemical and refinery heat exchanger use, has just been placed on the market.

Bearing the trade name "Lectrosonic," the tubing has been subjected to five years of extensive field tests, and has proved equal or superior to seamless carbon steel heat exchanger tubing, according to the company. Prices for the new line show savings ranging from 10 to 32 percent over grades of seamless tubing it has been designed to replace.

The new line was developed to meet the petrochemical industry's need for an electric-resistance, welded carbon-steel tube of uniform strength, dimensions and properties, and which is easily workable and less costly than seamless tubing.

"Lectrosonic" welded carbon-steel heat exchanger tubes are produced to ASTM Specifications A-214 and A-334 Grade C and identical ASME Specifications. They are produced in a complete range of sizes through 4½ inch outside diameter and in all normally required standard wall thicknesses. The Babcock & Wilcox Co.

Circle E19 green card, last page

Insulation Specification Manual Has Been Revised

A well known manual of insulation specifications has just been re-issued in an enlarged and thoroughly revised form. The new manual has been prepared for the power generation field as well as the chemical and petroleum industries covered by the earlier book. It has been completely rewritten by an engineering staff

Advertisement

Now Available . . . . .

THE AUTOMATIC PLANT

. . . . . *technology is ready, but close scrutiny of economics is essential*

by W. W. Hopwood
President, Hagan Chemicals & Controls, Inc.

There is no question that most of the hardware for a computer-controlled power or process plant is available today—however, we feel that enthusiasm for this concept has led to a glossing over of the economics of the situation. In addition, as the art of computer control stands today, reliability requirements have been compromised.

We have taken these, and the many other factors which bear on the successful installation of computer control, into consideration in formulating our position, which is: Only as many steps towards complete computer control should be taken as can be justified both technically and economically. Since it is almost impossible to compute the dynamics of a process in advance of its operation, it is only logical to establish a sequence which will permit each step to be tested and justified before the next step is taken. Of course, if a specific situation requires it, the complete package can be installed at once. Here are the steps which we at Hagan feel are reasonable and economically sound:

1. Install a solid state electronic analog control system.
2. Install a solid state electronic scanning-logging data system.
3. Install computer capacity to compute from processed data.
4. Add programming capacity for automatic start-up and shut-down, as well as day by day operation.

Hagan equipment is designed to implement such a program. The Hagan PowrMag analog computer control system, featuring all solid state—magnetic amplifiers, requires minimum maintenance and provides a high degree of reliability and sensitivity with fast response. DC operation at the 1 to 9 volt level permits simple wiring, and the output is ideally suitable for use with the Kybernetes data processing-computing system.

We are ready, at this time, to take the computer control concept as far as the specific operation and management requirements determine.

Kybernetes put into operation at water works system in one day.

The Kybernetes system at an eastern water works *was installed and tested to be operational in one day*. Ninety-two inputs, representing flows, levels and pressures will be displayed as digital values on the main control console. In addition, two typewriters will print out the data for permanent records, and the system permits trend logging of selected variables without interfering with basic scanning. Alarm scanning of all incoming data is also performed automatically. If any variable exceeds preset minimum or maximum values, a visual and audible alarm alerts the operator to take corrective action. Installation test showed that the Kybernetes system was handling all available inputs.

Hagan PowrMag provides high reliability analog computer control

Utilizing magnetic amplifiers as the basic unit, the Hagan PowrMag system represents the most advanced electronic approach to industrial process control. Reliability and long, maintenance-free life are assured in every phase of the system, including inputs, analog computer-controllers, remote control stations and final control elements.

The PowrMag amplifier is a high gain, DC, magnetic amplifier composed of toroidal magnetic cores, windings and silicon diodes . . . all potted in epoxy resin and sealed

in a steel can—thus assuring reliability and long, tamper-proof life. Associated with the amplifier are remote control stations which provide the desired functions, and the whole unit may be mounted on panels up to ¼" thick, occupying only 2½" x 5¼". Utilizing a 1 to 9V DC input and output signal, the system is unaffected by stray AC, information is not deteriorated between measured variable and the final control element. Signals may also be fed to data processors or recorders without interfering with the control action.

PowrMag systems are currently being installed on (1) a 1,250,000 #/hr pulverized coal fired, divided furnace, controlled-circulation steam generation unit for a southern utility, (2) a 2,310,000 #/hr pulverized coal fired, single furnace, single drum, dry bottom reheat type steam generator for a midwest utility, and (3) a 1,700,000 #/hr 2400 psig, 1050°/1000° controlled circulation boiler at an eastern utility.

The Hagan PowrMag system is simple, yet extremely flexible in application. The basic elements are interchangeable, which limits stocking problems. Each element in the system is designed for long, trouble-free life, and adjustment of any loop is easy and exact. Here is the answer to the demand for a sensitive, accurate system with high stability and the utmost in reliability.

Kybernetes data processing system adds new flexibility

The new Kybernetes Series 2000 allows a new approach to the problem of scanning, logging, alarm scanning, computing, optimizing, programming and the many other uses to which data processing systems are put. Of modular construction and utilizing solid state components, the new Kybernetes features optimum reliability allied with such flexibility that a new dimension is added to data processing.

The basic system is a simple logging unit for recording process data on a log sheet or other output device. Because of its modular construction, this basic system can be expanded in both number of points handled and the complexity of the operations performed. This concept is in keeping with the Hagan approach to computer control, since any one or all of these functions may be added as it becomes desirable:

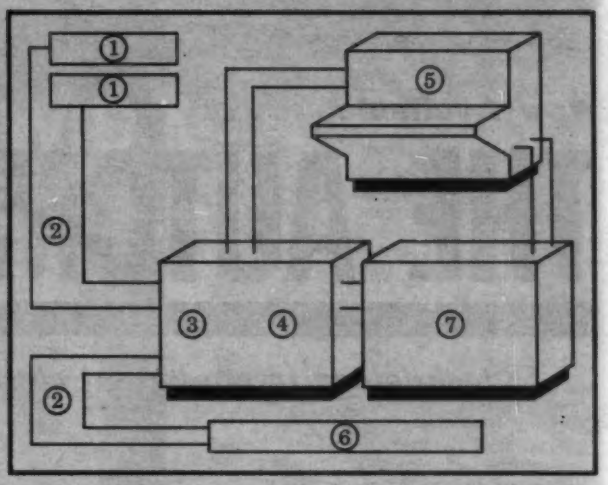
1. Alarm scanning.
2. Printed or visual trend logging of selected variables.
3. Computing or integrating.
4. Automatic programming and optimum setting of control.

With an accuracy of 0.1% on all inputs, the new Kybernetes reflects the simplified design logic which guided its design, and the reliability of all components is assured by the use of solid state devices.

In addition to numerous chemical, refinery and general process installations, a Kybernetes system will process data on the largest steam boiler in the world—a 3,850,000 #/hr unit now under construction at a southern utility.

Maximum usefulness with minimum investment characterizes this development. Field tested and proved, the new Kybernetes data processing unit will provide long, trouble-free operation.

The diagram illustrates a typical installation of Hagan PowrMag units in association with a Kybernetes data system for overall plant control.



1. Transducers convert measured variables into DC electrical signals and transmit to the central analog control computer via two-wire electrical cable. These signals may be recorded or indicated.

2. Two-wire, color coded cable, terminated with vibration-proof taper pin fittings, permits no-lag electric transmission of the measured process even in the largest plant. The system is designed so that the DC signal is, for all practical purposes, unaffected by stray AC potentials. The taper pin connections eliminate all field soldering or terminal box connections.

3. Signals enter plug-in patchboard section of analog computer. Patchboard is arranged to permit interconnection of system in any desired manner by simply moving taper pin connections.

4. PowrMag analog computer control elements are composed of operational magnetic amplifiers. They perform all the required control operations such as addition, subtraction, ratioing, integrating (reset), differentiating (rate), multiplication (proportional band), etc.

5. Remote control stations, located on the central control panel, provide process set point, bias, ratio, and other manually set control operations and have both output and null indicators.

6. Final control elements such as valve positioners, damper operators, saturable reactors, etc., receive the signal from the computer and act on the process function under control.

7. Series 2000 Kybernetes data processing system (see Bulletin MSP 161) can log, scan, trend log, read out, compute and integrate data as received from the PowrMag transducers, thermocouples, and other primary sensing elements. In addition, the Kybernetes digital computations can be used to return set point instructions to the PowrMag analog computer to optimize process controls.

For Bulletin MSP 161 (Kybernetes Data Processing Systems) and MSP 163 (PowrMag Electronic Control Systems), write to:

HAGAN CHEMICALS & CONTROLS, INC.

DIVISIONS: CALGON COMPANY, HALL LABORATORIES

HAGAN BUILDING, PITTSBURGH 30, PA.
In Canada: Hagan Corporation (Canada) Limited, Toronto
European Division: Via Fiumendosa No. 13, Milano, Italy

401-1-85

Equipment . . .

so that procedures are in accord with modern practices and that the specifications include the new insulations developed in recent years.

Among the modern installation methods covered by the manual is the application of tank insulation over welded pins. Specifications for such newer materials Thermobestos, Superex-M, Banroc H. T. Block, Spintex for tanks, No. 301 Cement are included in the book. Among the new specifications are those for G-2 Refractory Cement used as a catalytic reactor lining, insulation for vertical oil type heaters and other uses.

The new tables include the recommended thicknesses for both steam generating plants and process equipment based on average economic conditions for the industries and the recommended thicknesses for Rock Cork to prevent sweating. These are given in the simplified thicknesses. Johns-Manville Corp.

Circle E20 green card, last page

Expansion Joint Has Only One Lubrication Fitting

Complete and uniform lubrication of plastic packing material is provided by a lubricant dispersion ring on a new expansion joint called RAM-PAK. Plastic packing can be replaced without taking the joint out of service.

Only one lubrication fitting is needed to lubricate the joint and it has a specially designed positive-stop.

An internal guide acts as inward and outward limit stop to prevent the slip from being pulled out of the body. When the guide is in contact with the lubricant dispersion ring, the full pressure thrust is transferred back to the body. Adsco Div. Yuba Consolidated Industries.

Circle E21 green card, last page

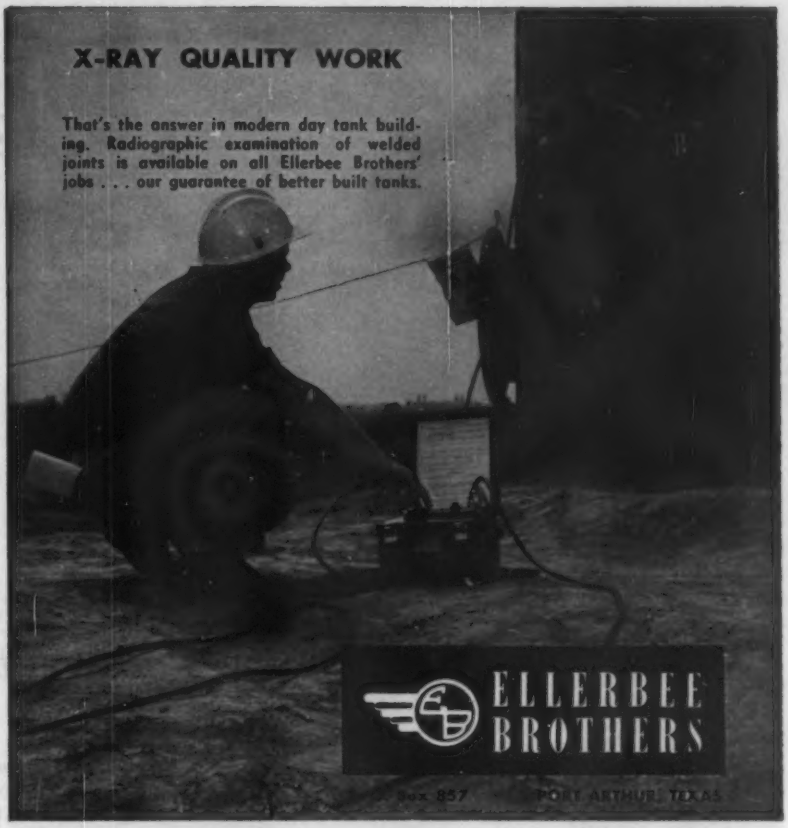
Chromotography Ionization Detector Is Very Sensitive

A highly-sensitive ionization detector for gas and vapor chromatography has been developed.

Designed for use with the Kromo-Tog, the new ionization detector is at least 1,000 times more sensitive than the type using thermal conductivity. With it, a wider range of compounds, including fixed gases, can be analyzed. Fast linear repsonse is achieved over wide concentration ranges.

The instrument design is simple, compact and practical. It is completely nonradioactive and uses no hazardous materials. Attachment to the Kromo-Tog is fast and easy.

In operation, electrons for ionization are supplied by emission, with the detector responsive to the sample rather than the carrier. Small changes in temperature or pressure have no adverse effect. Flow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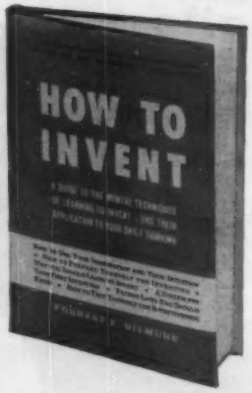

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By Forrest E. Gilmore

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A guide to the mental techniques of learning to invent . . . and their application to your daily thinking.

In easy-to-read and understand language this book shows you: how to use your intuition and imagination, how to prepare for invention, how to test your Ingenuity Quotient, when and where to invent, how to find time to invent, ways to profit from your invention, how to record your observations, why some potential inventors fail.

The book also contains a detailed discussion of patent practices you should know such as: how to decide what is patentable, how to go about obtaining a patent, what a patent really means, how to protect your patent from the beginning.

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Tailor-made, tough and chemically inert...

. . . these J-M Chempac Teflon components combat chemical and solvent action!*

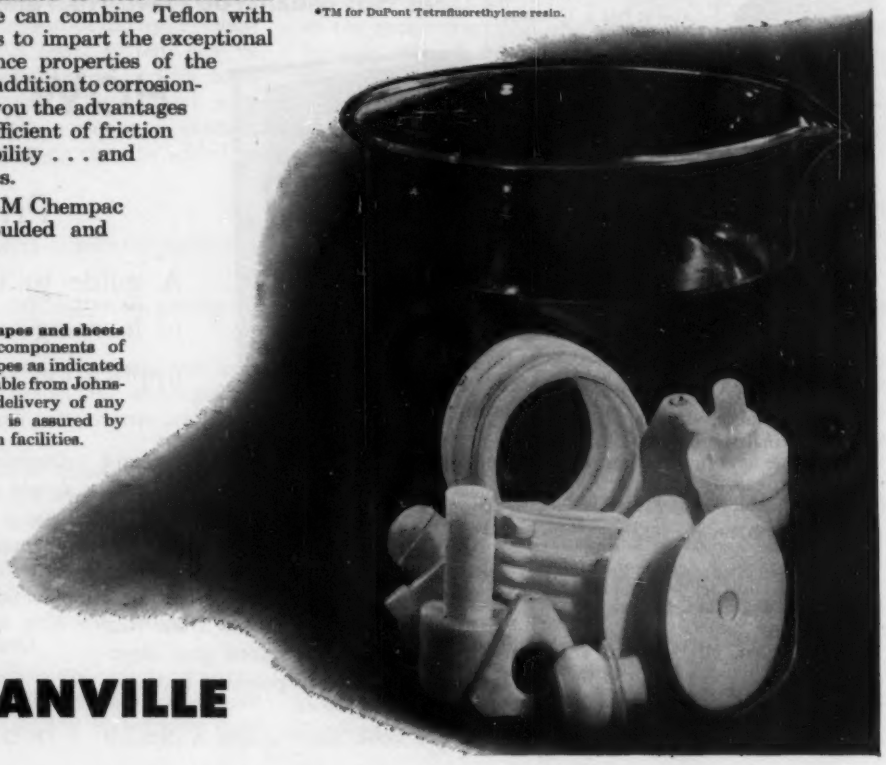
SMALL OR LARGE . . . intricate or simple . . . J-M Chempac® Teflon components have proved their exceptional resistance to the constant attack of corrosive chemicals in rugged service.

Look to J-M for Teflon packings, gaskets, and moulded shapes made to your exact specifications . . . or for parts that are machined to close dimensional tolerances. Moreover, we can combine Teflon with top quality J-M asbestos to impart the exceptional sealing and heat-resistance properties of the "magic mineral." And in addition to corrosion-resistance, Teflon gives you the advantages of an extremely low coefficient of friction . . . toughness and flexibility . . . and weight-saving possibilities.

You can also obtain J-M Chempac Teflon Packings in moulded and braided types for pumps and valves . . . in a wide range of flange and envelope-type gaskets . . . in rings, cups, sheets and tapes. Your J-M Packings Distributor can supply your needs. Or write Johns-Manville, Box 14, New York 16, New York. In Canada: Port Credit, Ontario.

*TM for DuPont Tetrafluorethylene resin.

Teflon rods, tubes, tapes and sheets —in addition to components of varied sizes and shapes as indicated here—are also available from Johns-Manville. Prompt delivery of any quantity you need is assured by new J-M production facilities.



JOHNS-MANVILLE JM PRODUCTS

JOHNS-MANVILLE

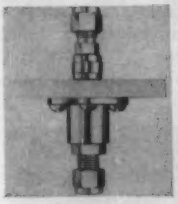
Equipment . . .

may be interrupted for sampling, but is held constant during an analysis. The new detector is suitable for use with either capillary or packed columns. Helium and argon are the preferred carrier gases. Ready control of the ionizing energy provides flexibility for special techniques. Burrell Corp.

Circle E22 green card, last page

Adapter For Flush Mounting Instrument Panel Fittings

Development of a new adapter unit for flush rear-mounting of Swagelok Bulkhead Quick Connect Fittings on instrument panels, has been announced.



Application of this flange permits a more uniform and attractive appearance on the front of the panel board as illustrated, since there will be no projecting parts of the quick-connect. Better housekeeping, and prevention of defacement of the panel board front also are advantages.

These new Flush-mount Flanges will fit ¼ and ⅜ inch Swagelok Bulkhead Quick Connect. Crawford Fitting Co.

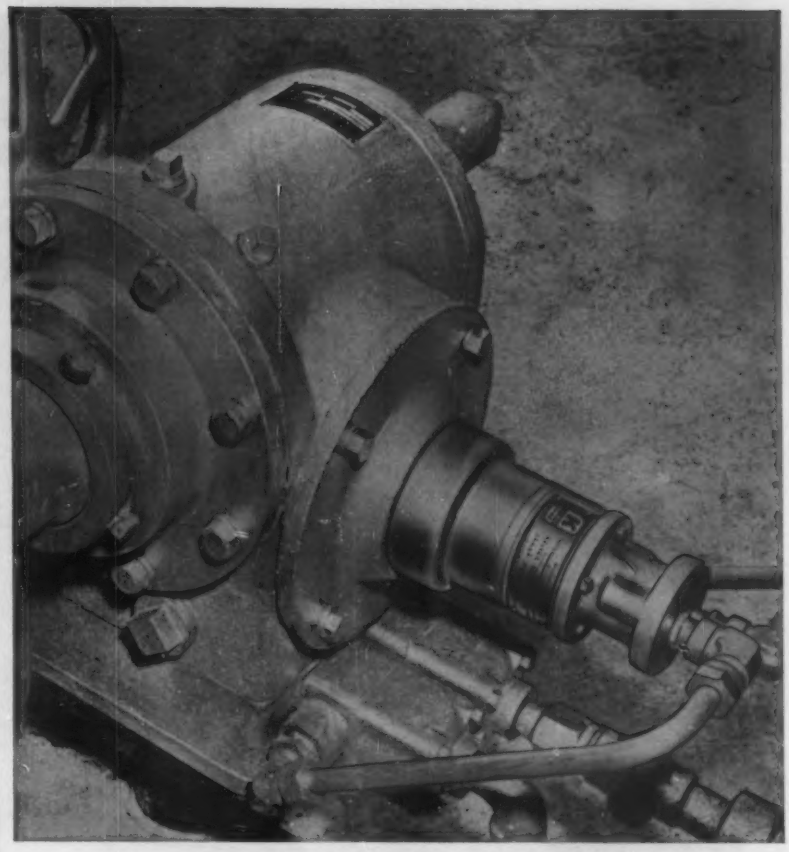
Circle E23 green card, last page

Refinery Products Tested Quickly By Distillation

The testing of refinery products for volatility control can be carried out quickly and accurately with a new automatic distillation unit. Just introduced to the United States, the apparatus is made under license from the British Petroleum Co., Ltd.

The unit is based upon a rapid distillation method for the routine testing of refinery products when the value of a single point on the distillation curve provides sufficient information for day to day volatility control.

Entirely automatic, the apparatus carries out a distillation in minutes—an operation which takes the best part of an hour by other methods. Reproducibility



Gardner-Denver axial piston air motor operates valve in pipeline safely, by remote control. Sizes from ¼ to 2¾ hp.

Idea power for refinery modernization

Look to Gardner-Denver air motors for any power applications that call for:

Spark-free operation—can be used safely for applications that demand nonsparking characteristics.

Control flexibility—remote control possibilities are almost limitless.

Variable speed—from zero to full.

Reversible operation—single control provides efficient power in either direction.

Quick starts and stops—instant response to control commands. Torque output consistent at any speed.

Cool performance—air motors run cool, won't burn out when run to stall.

Output from ⅛ to 16 hp.

Write for bulletins.

Gardner-Denver rotary vane air motors from ¼ to 1.6 hp.

Gardner-Denver 5-cylinder radial air motors from 3 to 16 hp.

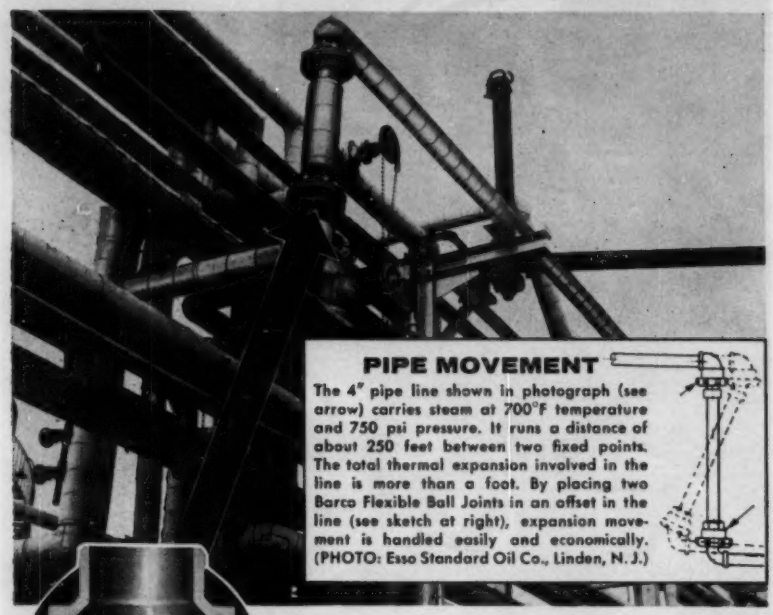
EQUIPMENT TODAY FOR THE CHALLENGE OF TOMORROW

GARDNER-DENVER

Gardner-Denver Company, Quincy, Illinois

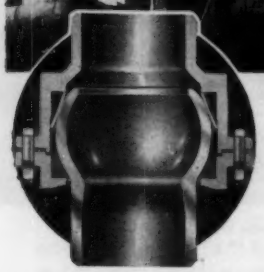
In Canada: Gardner-Denver Company (Canada), Ltd., 14 Curity Ave., Toronto 16, Ontario

How Refinery Handles 700°F. STEAM . . . PIPE EXPANSION



PIPE MOVEMENT

The 4" pipe line shown in photograph (see arrow) carries steam at 700°F temperature and 750 psi pressure. It runs a distance of about 250 feet between two fixed points. The total thermal expansion involved in the line is more than a foot. By placing two Barco Flexible Ball Joints in an offset in the line (see sketch at right), expansion movement is handled easily and economically. (PHOTO: Esso Standard Oil Co., Linden, N. J.)



BARCO HT (HIGH TEMP.) Flexible BALL JOINTS

SAVE VALUABLE SPACE

ADVANTAGES:

SAVE SPACE—Barco Ball Joints are used to perform functions similar to U-bends or pipe loops—But with much less space required and often LOWER COST.

NO PRESSURE THRUST—Expensive anchoring or bracing not required to hold piping in place or in line.

HIGH TEMPERATURE, PRESSURE—Wide choice of materials in new Barco HT Joints.

SIMPLE—Easy to solve virtually any problem with aid of two or three Barco Joints.

The Barco HT (High Temperature) Flexible Ball Joint is a new development. It is *the key* to solving many PIPE EXPANSION PROBLEMS where high temperatures and pressures are encountered. The outer sealing gasket is a special, high temperature ring. The inner take up ring is self-adjusting to thermal expansion and maintains tight sealing action without building up high resistance (friction) to turning or angular flexing. HT joints can be supplied in sizes from 1" to 12", angle or straight, and can be fabricated from materials to withstand as much as 1000°F, 1200°F, or even 1400°F, under certain conditions.

Local Barco Field Engineers will be glad to give you full information and recommendations. Call or write today.

Send for this BULLETIN 31

"How to Solve Piping Flexibility Problems". Complete with piping layout drawings and illustrations. Shows how to cut costs, save time, and do a better job!

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The Only Truly Complete Line of Flexible Ball, Swivel, Swing and Rotary Joints

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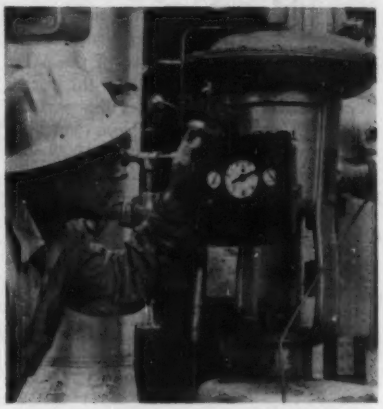
Equipment . . .

is better than by standard methods.

Here is how the test is made: Ten millilitres of the sample to be tested is placed in a flask. A thermocouple is inserted into the neck of the flask and the receiver is placed into position.

A heater is switched on and when the selected temperature is reached an automatic cutout turns off the heater. The volume of the distillation to the nearest 0.05 ml is then noted, after allowing half a minute for draining. After each distillation, the residue in the flask is removed by suction. The complete operation takes no longer than 10 minutes, of which less than three minutes is operator's time. Testing Machines, Inc.

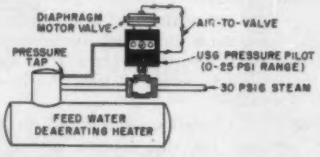
Circle E24 green card, last page



Valve-Mounted Pilot Controls Press. On Temp.

At six field locations in Cities Service Oil Co.'s new asphalt refinery in Linden, N. J., valve-mounted instruments are providing local, low-cost indication of temperature or pressure together with pneumatic proportional control. Except for routine maintenance, these control systems have given continuous, trouble-free service since July, 1958, when the refinery went on stream.

As shown in the accompanying illustrations, the instruments mount on the yokes of the pneumatic-operated diaphragm motor valves that they position to provide automatic control of a process unit. They are a type commonly referred to as "Pilot" controllers. Five have Bour-



don tube elements for pressure control and one has a filled thermal system for temperature control. Both the actual value of the process variable and the control set point are indicated by pointers on the 3½-inch center dial of the controller.

Supplementing other extensive instru-

Manufactured and installed by Babcock-Wilcox & Goldie McCulloch, Limited, this B&W CO Boiler uses 222,400 lb/hr catalytic gases at 600 F. These gases contain 4.6 per cent CO (by volume) plus traces of entrained hydro-carbons.

B&W CO BOILER SLASHES STEAM GENERATING FUEL COSTS FOR BRITISH AMERICAN OIL

At the Montreal East Refinery of the British American Oil Company, a B&W CO Boiler installed in October, 1957, has proved to be a sound investment. Waste CO gases, normally released to the atmosphere, are put to work to generate 60,000 pounds of steam per hour. Add to this the 90,000 lb per hour generated by the unit from conventional fuels and you have a total output of 150,000 lb per hour. No wonder British American points to this unit with pride. It saves them thousands of dollars yearly in fuel costs; furnishes a dependable supply of high quality steam that helps over-all refinery efficiency.

Similar Savings for your Refinery. By recovering sensible heat and the heat of combustibles in the waste gases, a B&W CO Boiler can mean similar savings for your refinery. In addition, B&W CO Boilers give your community relations a big assist by removing entrained hydro-carbons from waste gases—thereby helping to lick the troublesome problem of air pollution.

Find out how a B&W CO Boiler can Help you Cut Costs. These are practical advantages that can help improve your refinery operations. There are many more that add up to increased efficiency and economy. Get the complete story by writing for Bulletin G-87, The Babcock & Wilcox Company, Barberton, Ohio.

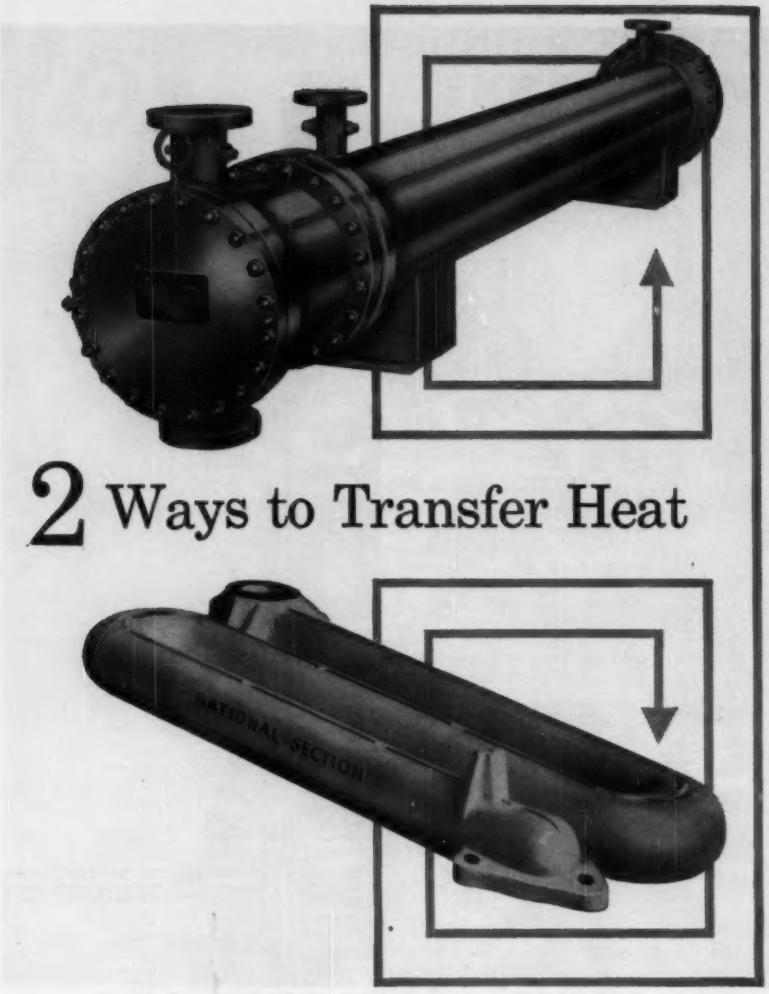
CO-101

B&W

THE BABCOCK & WILCOX COMPANY

BOILER DIVISION

For more data on advertised products, use Readers' Service Cards, last page.



2 Ways to Transfer Heat

Problems of heat exchange and process cooling in the chemical and petroleum industries are best solved when limitations of specific materials, shapes and fabrication methods are reduced to a minimum.

When National-U.S. engineers are called in early enough, they are frequently able to apply an unusual solution to a particular problem, because of their wide range of experience over a broad spectrum of industry. And *only* National-U.S. can offer *both* conventional heat exchange equipment in a complete range of metals *plus* units built from assemblies of corrosion-resistant cast iron.

For details, see REFINERY CATALOG or contact . . .

58-01

Heat Transfer Division

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Equipment . . .

mentation with indications and records in a centralized control room, the "Pressure Pilots" perform such workaday functions as regulating steam pressures to feedwater deaerating heaters, steam pressure reduction, and pressure control for a fuel oil recirculating pump. The temperature controller (range 50 to 400 F) regulates the temperature of fuel oil from a heater. Each arrangement is a closed loop system, maintaining secondary variables at desired values to aid operators in achieving the best over-all efficiency of plant operation. U. S. Gage Div., American Machine & Metals, Inc.

Circle E25 green card, last page

Plastic Packing Works At High Temperatures

A new plastic metallic packing, suitable for high pressures and temperatures which never needs replacement is now available.

Called "Lonsor," the metallic substance is said never to deteriorate or harden; consequently it never needs to be replaced, only added to.

It also eliminates the need for various sizes of packings; it comes in one-pound wrapped cakes and is easily broken off and stuffed into the box, gland or shaft by hand. Being pliable, the packing conforms to the rod or shaft and makes a perfect bearing surface. Its inherent self-lubricating properties, derived from its antimony content, results in frictionless running. Because of its pliability, it compensates for any inequalities which may exist in worn or out-of-round shafts.

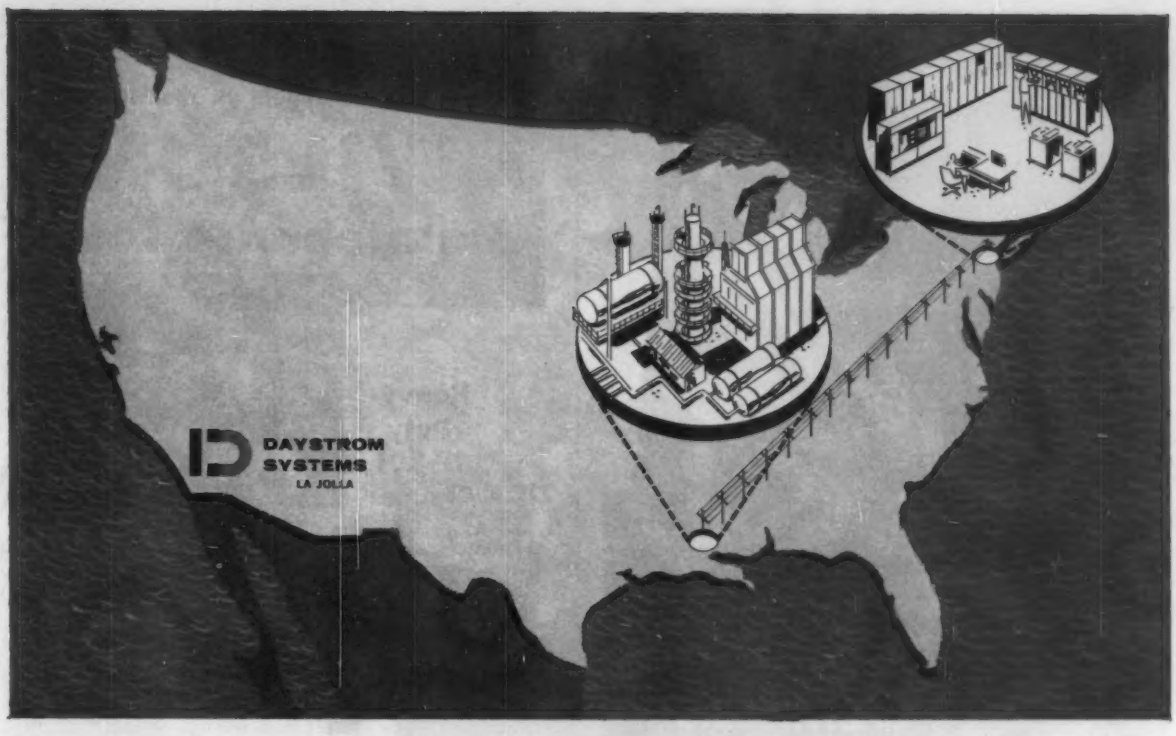
It will withstand high pressures and temperatures to 700 F and is impervious to water, steam, acid or oils. Newage Industries, Inc.

Circle E26 green card, last page

First Standards Published On Reinforced Plastics

The first standards ever published for reinforced plastic fabrications, a new six-page brochure, is available to engineers and designers on request.

The subject is covered in terms of the new visual standards as well as the most advanced material specifications including physical properties. The visual standards section features many comparative photographs of acceptable and unacceptable workmanship in common design configurations plus an evaluation of possible performance. The materials specifications section describes the important require-



Now...in addition to on-line computer systems

Operating and test data reduction via telephone link utilizing any computer facility

The new Daystrom TPR Scanning System represents a revolutionary approach with vast implications where there are requirements for immediate or continuous computer analysis of plant operating or test data. The availability of this new tool will influence industry's plans in a number of important areas, which include process studies, experimental test work in the military and nuclear areas, and testing for performance guarantees.

For the first time, the TPR (tape programmed raw) data scanner makes it possible and practical to link a test or operational plant facility directly to any computer in the country for instant computation of data. This is made possible by the utilization of standard telephone communication services, and permits stationing of all engineering and computer programming personnel at the project site, where all phases of the work may be handled.

The importance of this development is brought into sharp focus by the almost non-existence of computer facilities at actual plant or test sites. The utilization of telephone circuits completely circumvents this problem since it makes little difference whether the computer facility to be used is located in an adjoining building, company headquarters or at a rental facility. Distance represents no problem other than nominal telephone service charges.

Telephone communication of this type is a practical reality in the business machine field and is being used every day by leading companies for inventory control, accounting and other purposes. The Daystrom TPR Data Scanner is the first system that has been specifically designed to handle the problems involved in gathering large amounts of analog data peculiar to plant and test facility operation.

The TPR Data Scanner's feature of tape programming provides unlimited flexibility. This permits unrestricted application of the equipment to various types of facilities even though they may be completely different in nature.

Typical of the unequalled performance specifications are 0.1% accuracy at the 99% confidence level, together with extremely high signal to noise ratio at scanning rates up to 40 variables per second. 100% solid state circuitry and full parity checking are incorporated. Input channels may be as few as 100 or as many as 6000.

For further information, write or telephone Daystrom Systems, Dept. A-122, Miramar Road, La Jolla, Calif. GLencourt 4-0421.

Typical 2000 point system delivered to A major nuclear propulsion test facility.

DAYSTROM SYSTEMS
DIVISION OF DAYSTROM, INC.
Reliable computer control systems

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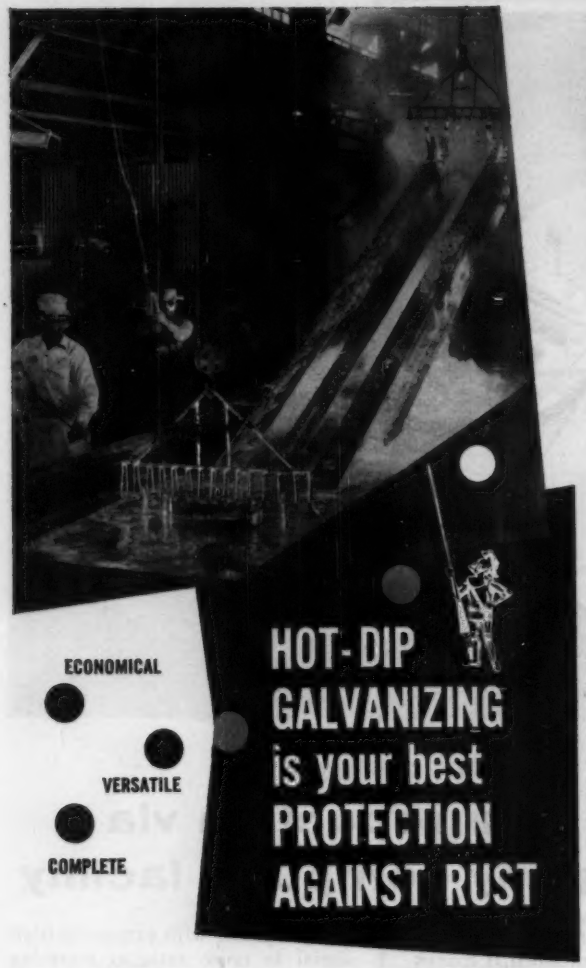


ECONOMICAL

VERSATILE

COMPLETE

HOT-DIP GALVANIZING is your best PROTECTION AGAINST RUST

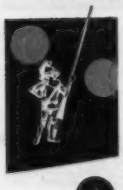
Economical Protection: Low initial cost, and long-life protection make hot-dip galvanizing the most economical rust preventative you can buy. Zinc coatings eliminate many maintenance costs; give additional life to vital structures.

Versatile Protection: The number of items that can be protected by galvanizing continually grows. The hot-dip method protects all types of iron and steel. Large or small, and under all conditions.

Complete Protection: Hot-dip galvanizing protects your structures and/or equipment completely. Complex shapes, inside surfaces, and all hard-to-reach areas receive the same uniform, long-life protective zinc coating.

Consult with Nowery J. Smith's corrosion prevention specialists during the design phase of your project. Get better protection from corrosion at less cost.

Think Nowery J. Smith Co. for Hot-Dip Galvanizing • Metallizing • Pickling • Sandblasting • Painting • Plastic Applications • Vessel Lining.



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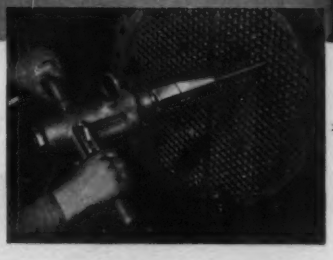
ONE OF THE SMITH INDUSTRIES —

Keep Heat Exchangers on the Line with

WILSON Maintenance Tools

Heavy-Duty TP-301 Cleaner

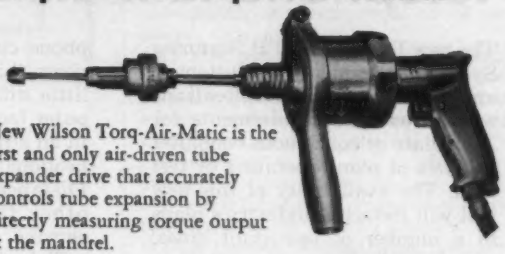


Positive air-driven, hollow rotary shaft, drill type tool. Tube is scavenged with air or water while cleaning.

Tube Expanders

Wilson Models 41 and 44 Tube Expanders incorporate an improved, adjustable ball bearing thrust collar and are designed for efficient, easy rolling and maximum roll length adjustment for various tube sheet thicknesses.

Torq-Air-Matic Expander Control



New Wilson Torq-Air-Matic is the first and only air-driven tube expander drive that accurately controls tube expansion by directly measuring torque output at the mandrel.

Tube Cutter

Wilson tube cutter is easy to use and does a fast job. Cutter sizes and shanks available to meet all heat exchanger requirements.

Write today for your copies of Wilson Tube Cleaner catalog No. 77 and Wilson Tube Expander catalog No. 88.

Representatives in principal cities
Thomas C. Wilson, Inc. • 21-11 44th Ave., Long Island City 1, N. Y.
Cable address: "Tubeclean", New York

WILSON TW888

TUBE CLEANERS • TUBE EXPANDERS

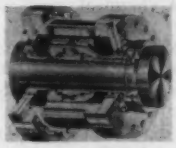
ments essential to the proper fabrication of serviceable structures.

The publication of these standards is regarded by the company as an important stride toward establishing useful industry guides for engineers and designers. Since the quality of reinforced plastic structures is highly dependent on individual workmanship, visual inspection is the simplest, easiest way of determining the quality of a part. While the appearance of various fabrications may vary somewhat from fabricator to fabricator, there are certain visually detectable defects that serve as a reliable guide to estimating serviceability and eliminate more elaborate testing procedures. The Ceilcote Co.

Circle E27 green card, last page

Mechanical Seal Prevents Agitator Shaft Leakage

A new series of mechanical seals have been developed for installation on sealed vessel agitator shafts. Known as MECHANIPAK seals, they are completely self-contained in a single unit for simple, quick installation.



The units are designed to prevent agitator shaft leakage at pressures up to 3,000 psi and to withstand temperatures in excess of 700°F, even in corrosive environments. The seals are currently available in sizes to fit any shaft. The Garlock Packing Co.

Circle E28 green card, last page

Continuous Lube Blending Discussed In Bulletin

A new bulletin for the petroleum industry has been announcced. Titled "Continuous Automatic Lube Blending," the 16-page bulletin discusses in detail the ideal system for continuous automatic blending of lube oils.

The bulletin contains a schematic plan of the lube oil blending system, a dimension drawing of a continuous mixer, copies of a typical Batch Record Printed Ticket and a Typical Log Sheet. Proportioneers Div., B-I-F Industries, Inc.

Circle E29 green card, last page

Article On Burner Design Available As Reprint

The advantages of using a flat flame burner for direct-fired heaters are discussed in an article on "Burner Design Gives More Uniform Heat."

This is a reprint of an article appearing in the February, 1959 issue of PETROLEUM REFINER and is available on request. The North American Mfg. Co.

Circle E30 green card, last page

60-Page Book On Caustic Potash Gives Properties

A new technical booklet on caustic potash is currently being offered. It presents the properties and handling of caustic potash based on the company's own

now at

Avondale

U. S. RUBBER LINING FOR INDUSTRY

(Left) Muriatic acid tank car being prepared for patch job of rubber lining. (Center foreground) Flanged 16" pipe being lined inside with ¼" natural hard rubber with chlorine resistance properties. (Right) Dredge pipes, 40" in diameter, to be lined inside with abrasive resistant and oil resistant neoprene.

Avondale now markets and installs U. S. Rubber's "Permobond" Tank Lining . . . a new service to industry. Included in this work are rubber lining process equipment, shafts, miscellaneous weldments, pipe and fittings. A complete vulcanizing plant has been provided with all-new equipment, including a 6′ I.D. x 40′ long steam vulcanizer (center background above). Let Avondale solve your corrosion problems . . . starting today.

AVONDALE

MARINE WAYS, INC.

VERSATILE BUILDER ON THE MISSISSIPPI

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totally enclosed, low friction, powerful

NYLON BEARINGS
low friction, long lasting

CHEVRON PACKING
never needs adjustment

SHAFT
straight through, stainless steel or monel

DISC
one piece, cast in choice of materials

HYCAR SEAT
never needs replacement

BODY
cast iron or cast steel

the MONOFLANGE MARK II

the valve that industry demanded*

*The motivating force behind the creation of this, and other new products soon to be announced, was the obvious industry need for this type of equipment. Henry Pratt MARKET ORIENTED valves are all new for 1960.

Usually, the most significant contributions to industry stem from ideas born of experience. Such a contribution is the Pratt MONOFLANGE MARK II—a really different valve. The difference is in design and conception—for here is a valve designed to meet the ever increasing need for a compact and sensible 150# valve. Drop-tight and ideal for throttling service, the MONOFLANGE MARK II is a versatile valve. Even the manual and automatic operators are new—all enclosed, powerful, rugged, and reliable. For a high quality, reasonably priced valve, consider the MONOFLANGE MARK II. Full particulars are available. Write for Bulletin 10-AB.

HENRY PRATT®

Monoflange MK-II
RUBBER SEAT BUTTERFLY VALVE

Creative Engineering for Fluid Systems

HENRY PRATT COMPANY
319 W. VAN BUREN ST., CHICAGO 7, ILL.
Representatives in Principal Cities

Equipment . . .

research, field experience and accepted sources.

Considerable detail is given to the physical and chemical properties of caustic potash and its water solutions with extensive use of tables and graphs to detail such properties as solubility, densities, Baumé hydrometer readings, specific gravity and heat of solutions. Safety precautions and methods of unloading and handling drums and tank cars of caustic potash are detailed along with three methods for dissolving the solid form. A section of the booklet is devoted to general information and conversion tables and a complete wall chart, "Precautions in Handling Caustic Potash," is printed on a fold-out page in the back of this booklet. Solvay Process Div. Allied Chemical Corp.

Circle E31 green card, last page

190-Page Valve Catalog Includes Engineering Data

Big 190-page catalog A-155 gives complete data on the company's line of valves for a wide variety of chemical applications.

It is divided into seven sections giving information, diagrams, and charts on the current line of AVECO valves, including:

- Section A—Needle Valves, both packless and conventional types.
- Section B—Globe & Stop Valves, packless diaphragm seal, bellows seal, and conventional types.
- Section C—Diaphragm Actuated Valves, packless diaphragm seal, bellows seal, reducing, back pressure, "on-off," and throttling types.
- Section D—Electric Motor & Solenoid Valves, either direct acting or auxiliary operated.
- Section E—Safety & Relief Valves, for liquid and gas service.
- Section F—Float Valves, for open and closed tanks.
- Section G—Miscellaneous Valves, for special and unusual applications.

Included also in the bulletin are extensive engineering charts and data, such as corrosion resistance tables for 15 metals and over 400 corrosive media in various conditions, conversion tables, valve flow capacity charts, etc., of value to chemical engineers. Associated Valve Co.

Circle E32 green card, last page

Portable Demineralizer For High Water Solids Removal

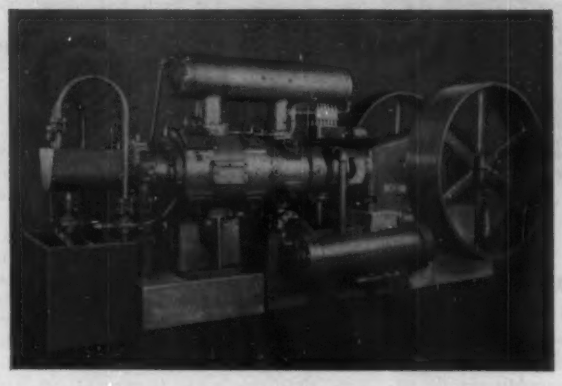
A new laboratory demineralizer for use whenever small quantities of exceptionally high quality water are required, has been manufactured.

The demineralizer is a self-contained, portable unit for either laboratory or plant use. It will remove all but minute traces of ionized solids from the water including such weakly ionized materials as silica and carbon dioxide, and thereby produce a water of much higher quality than is possible by distillation.

The ion exchange material is composed of cation and anion resins, inti-

NORWALK

HIGH PRESSURE COMPRESSOR



This 5 stage, 14″ stroke, heavy-duty tandem compressor develops 3000 lb. p.s.i.g. in capacities to 31,000 c.f.h.

Every Norwalk compressor is test-run at the factory, then taken down for complete inspection before reassembly and shipment.

Norwalk makes compressors from single stage to six stages; from 125 to 31,000 psi pressure; for gases listed below:

ACETYLENE	ETHYLENE
AIR	HCL
ARGON	HELIUM
CERTAIN HYDRO CARBONS	HYDROGEN
CO and CO_2	NITROGEN
ETHANE	NITROUS OXIDE
	OXYGEN

For full details, write for Catalog 44

NORWALK COMPANY, INC.

SOUTH NORWALK, CONNECTICUT

Established 1864

As SIMPLE and Dependable as the Pull of a MAGNET!

A sleeve, raised and lowered within a non-magnetic tube, attracts or releases an Alnico magnet attached to a mercury switch. Basically, this is Magnetrol.

MAGNETROL

The Simplest, Most Versatile LIQUID LEVEL CONTROL Ever Devised!

Linked to liquid level by infallible magnetic force, Magnetrol is free from the limitations inherent in mechanical or electrical controls. With the actuating magnet rated at 98% of initial strength after 30 years, Magnetrol has *infinite operating life,* with practically no maintenance at all. There are no wearing parts to get out of order.

What's more, Magnetrol's simple operating principle permits easy, economical modification of standard units to meet *any* pressure, temperature or corrosion requirements. That's why there's practically no limit to Magnetrol's use. It's also why "specials" are likely to be standard with us. Magnetrol units control level changes from .0025-in. to 150-ft. —with single or multi-stage switching.

MAGNETROL, Inc.

SEND COUPON FOR DETAILS

MAGNETROL, Inc. 2112 S. Marshall Blvd., Chicago 23, Illinois
Please send me catalog data and full information on Magnetrol Liquid Level Controls.

Name_____

Company_____

Address_____

Zone_____ State_____

For more data on advertised products, use Readers' Service Cards, last page.

mately mixed. The resultant effect is that of an almost infinite number of separate cation and anion exchange processes. The effluent water quality therefore is better than that obtainable by separate cation and anion exchange, where the cation and anion exchange resins are in separate columns. Pure water can be produced rapidly and economically by simply connecting the unit to any convenient water source, such as a city water tap. Betz Laboratories, Inc.

Circle E33 green card, last page

Heat Exchange Equipment Covered In New Bulletin

Equipment catalogued in a new heat transfer equipment bulletin includes heat exchangers, fired indirect heaters, tank heaters, tank suction and line heaters, process heaters and coolers, packaged boilers, as well as custom built equipment.

Consisting of pressure tubing to which longitudinal U-shaped channels have been resistance welded, the Brown finned tube has five to ten times the heat transfer surface area of ordinary tubing. Permitting more heat to be transferred per lineal foot results in more positive heat transfer, a decrease in size of heaters, lower fabricating costs, and lower skin temperatures.

The unique features of these widely used exchangers are described which include their ability to be used for any duty, so that they never become obsolete when a plant process changes. When the duty changes, a group of hairpin sections can be easily reassembled into a new series-parallel arrangement. This permits short-notice changes with little or no new equipment. Brown Fintube Co.

Circle E34 green card, last page

Remote Control Actuator Slips On Handwheel Shaft

A completely new, high torque, rotary actuator for remote and automatic control of industrial equipment has been announced. The SM-18 Shaftrol Actuator provides low cost control for variable speed drives, valves, pumps, reactors and machine tools. It is available with a built-in precision potentiometer which is gear connected to the output shaft through a wide choice of ratios so that from 1/16 to 40 shaft revolutions corresponds to full scale control. The pitentiometer provides remote indication of position on a dial or meter, or serves in automatic control circuits.

Ratings of ¾ hp are available in single and three phase styles with 500-watt units offered in two phases, servo types. A typical unit delivers 200 inch pounds at 50 rpm for remote or automatic control of the sliding motor base of variable pitch sheave drives. The hollow shaft mounting permits manufacturers to offer remote and automatic control as an optional feature without re-design of their equipment. The Shaftrol Actuator slips on the control shaft in place of the standard handwheel. The Jordan Co.

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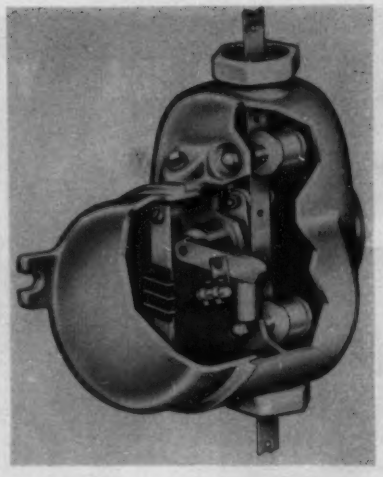


Tank Gage Alarm Control Detects Broken Tape

The Varec Slack Take Alarm Control allows a tank gager, reading an automatic tank gage, to immediately detect a broken tape or any abnormal slackening of the tape at the time of reading and thus reject the reading at the receiver or ignore it at the gage head.

Construction is very simple throughout. A Mercury switch is held into position by an arm attached to an idler pulley that rides against the gauge tape. Should the tape break or become abnormally slack, the Mercury switch will tilt to either an open or closed (depending on which is normal for the particular installation) position. Either visual or audible alarms or any other signaling device may be wired into the switch. The control mechanism is contained in an "in-line" housing fitted with 1½ NPT connections.

The alarm control may be installed in the field to an existing pulse code telemetering system very easily and inexpensively or it may be included with the original order of a pulse code telemetering system. The Vapor Recovery Systems Co.

Circle E36 green card, last page

17 Lab Corrosion Tests Made On Coal Tar Epoxies

Compilation of 17 laboratory tests shows what to expect when coal tar epoxies are exposed to attack of various corrosive solutions and environments. Tests include salts, acids, caustics, bleach, petroleum products, distilled water and weathering. Comparative performances of four leading coal tar epoxies illustrated and described for each test. Amercoat Corp.

Circle E37 green card, last page

Tower Packing Resists Hot Strong Alkali Solutions

A new ceramic tower packing composition which provides improved resistance to hot, strongly alkaline solutions has been announced.

Designated Body 97 and available at present only in Raschig Rings with outside diameters of from ¾ to 4 inches, the new composition has proven highly satisfactory in 10 percent sodium hydroxide at 150° F in actual field applications. Laboratory corrosion tests indicate that the new formulation will withstand temperatures approaching 300° F in alkaline service.

New Body 97 ceramic composition is also resistant to salts and non-acidic oxidizing solutions such as sodium hypochlorite. It is not recommended for use with acid systems. The U. S. Stoneware Co.

Circle E38 green card, last page

Pressure Reducing Valves Available In Larger Sizes

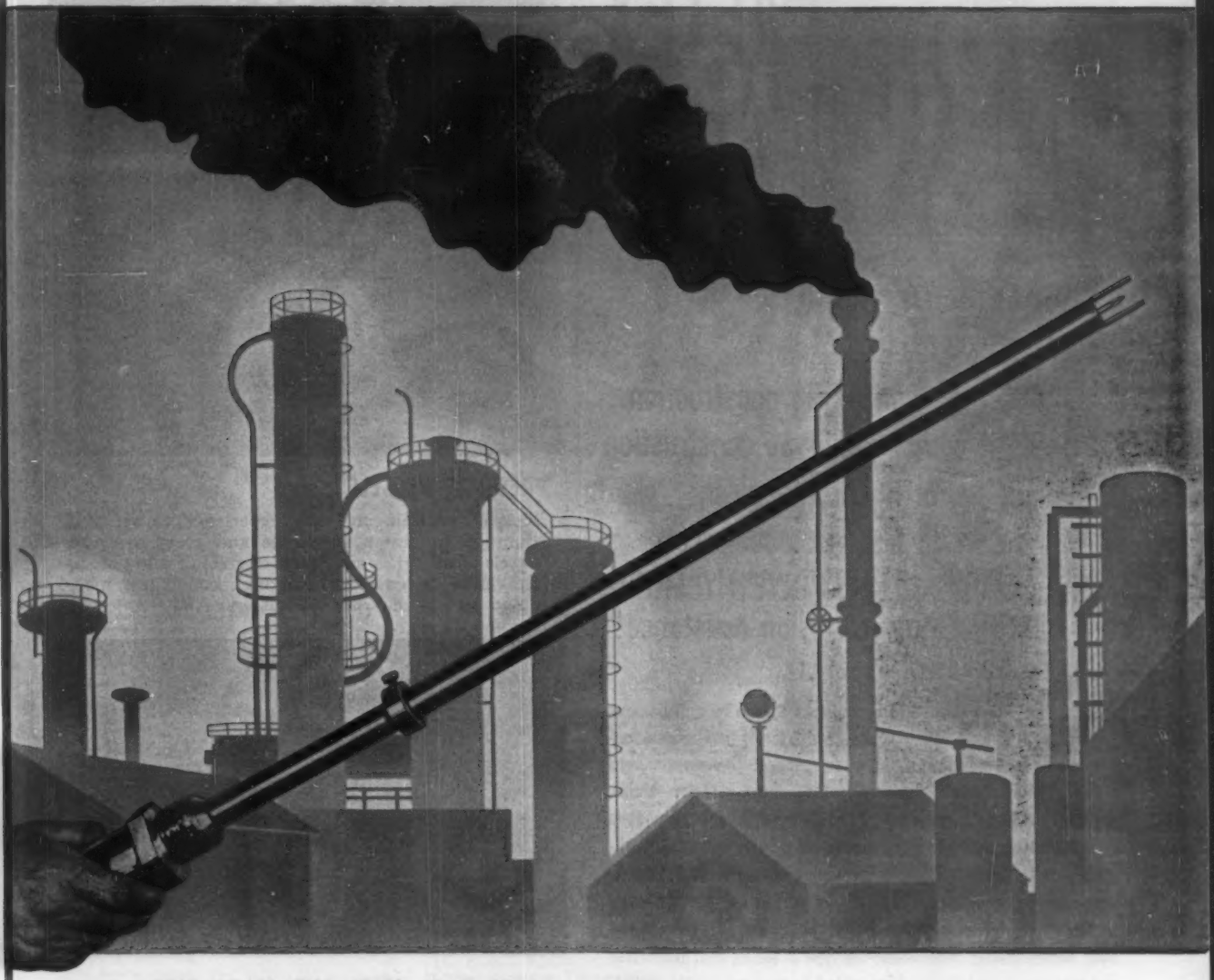
Introduced earlier this year, the RVA Pressure Reducing Valve is now available in the larger sizes from 1 to 1½ inches, as well as ⅜ through ¾ inches.

The RVA Pressure Reducing Valve, designed to control steam, air, oil, and non-toxic, non-flammable gases, is a diaphragm actuated, direct acting valve. It automatically reduces high pressure to a lower pressure—and holds it. Pressure reduction remains constant despite changes in the high pressure line. Construction features are a high pressure cast iron body (ASTM Class 35) with a precision ground stainless steel ball and valve seat. The Clark Mfg. Co.

Circle E39 green card, last page

Now that you have read about the newest and most efficient pieces of new equipment for your plant, be sure to use the reader's service card on page 487 to get more complete information. Simply circle the "E" number of the item you're interested in and mail.

Thousands going up the stack?



Reduce Flaring Losses
Control Air Pollution
with the "Anemotherm" Probe–Type Gas Flow Meter

You can stop profits from going up the flare stack with the new "Anemotherm" *Probe-Type* Gas Flow Meter. This *electronic, stainless steel* instrument quickly locates points of loss . . . accurately measures gas flow from 10 to 15,000 FPM with a scale range of 500 to 1. Refineries report savings of thousands of dollars per day.

The new "Anemotherm" Gas Flow Meter offers many exclusive features. Sixteen probe meters can be connected to one strip recorder so that flow in sixteen process lines can be observed and recorded by one instrument. The probe is self-compensating for ambient temperature and can be used in gas streams to 300°F. The probe has fast response, is corrosion resistant and streamlined. Accuracy is ± 5% of meter reading. The "Anemotherm" Gas Flow Meter is easy to install and easy to clean.

Look into the money-saving accuracy and efficiency of the "Anemotherm" Gas Flow Meter. For complete engineering data send for Technical Bulletin 5000.

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ANEMOSTAT CORPORATION OF AMERICA

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Representatives in Principal Cities

AC1369

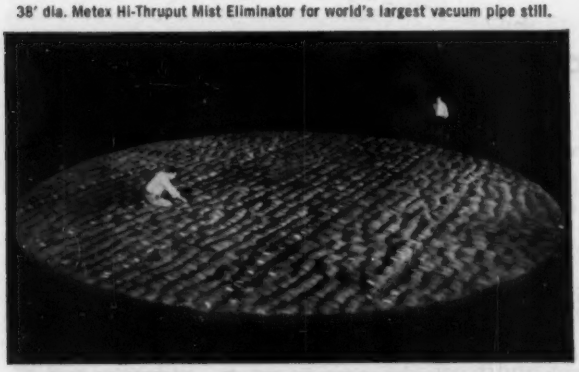
METEX MIST ELIMINATORS

...the First name in knitted wire entrainment separators!

FIRST with strip-type construction
FIRST with wound-type construction
FIRST with Hi-Thruput mesh
FIRST with fiberglass coalescers
NOW FIRST AGAIN with POLYETHYLENE for maximum corrosion resistance!

Since 1943, when it first introduced knitted wire entrainment separators—Metal Textile has been consistently first in introducing new developments to the field. In response to requests from chemical and processing engineers throughout industry—Metex engineers have utilized new materials...developed special meshes ...initiated revolutionary techniques to provide low-cost, high-efficiency answers to the most complex entrainment problems. Your specific needs can be similarly solved. Our engineers, backed by the most extensive research and production facilities in the field, will be glad to recommend the type of Metex Mist Eliminator and method of installation best suited to your particular operating conditions. For latest design guides, write or call for Bulletin ME-9: Metal Textile Corporation, Roselle, New Jersey.

38' dia. Metex Hi-Thruput Mist Eliminator for world's largest vacuum pipe still.



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A DIVISION OF GENERAL CABLE CORPORATION

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PRESSURE VESSELS

Backed by a half-century of experience, we are well equipped to design, fabricate and erect pressure vessels of all types and sizes, of steel or alloy steel, for liquid or gas. All standard codes are met, including ASME, API-ASME and API.

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We have earned a reputation as a dependable source for fabricated pipe to meet a wide variety of applications. Carbon steel, stainless steel, nickel clad, stainless clad, monel clad, wrought iron . . . from 14" diameter and larger. Piling, dredge pipe and all accessories for the pipe line are our specialties.

SINCE 1910 we have specialized in steel plate fabrication. Posey Iron has a wide background of engineering experience and know-how. Let us quote on your next job.

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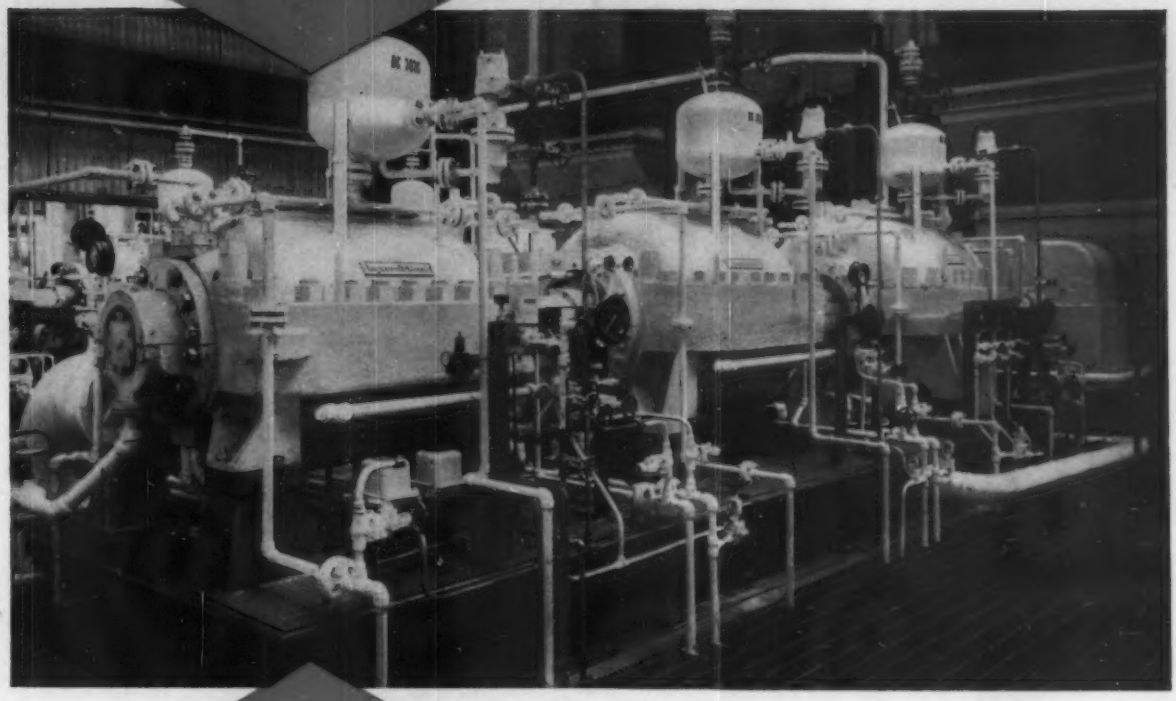

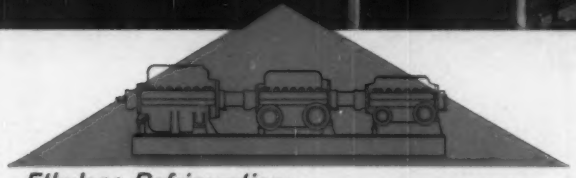

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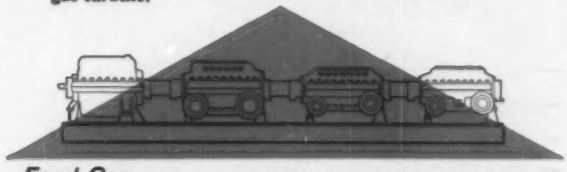

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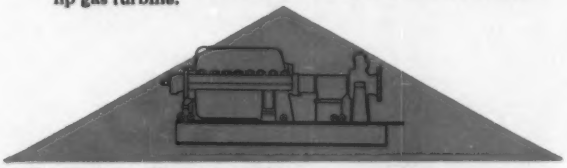

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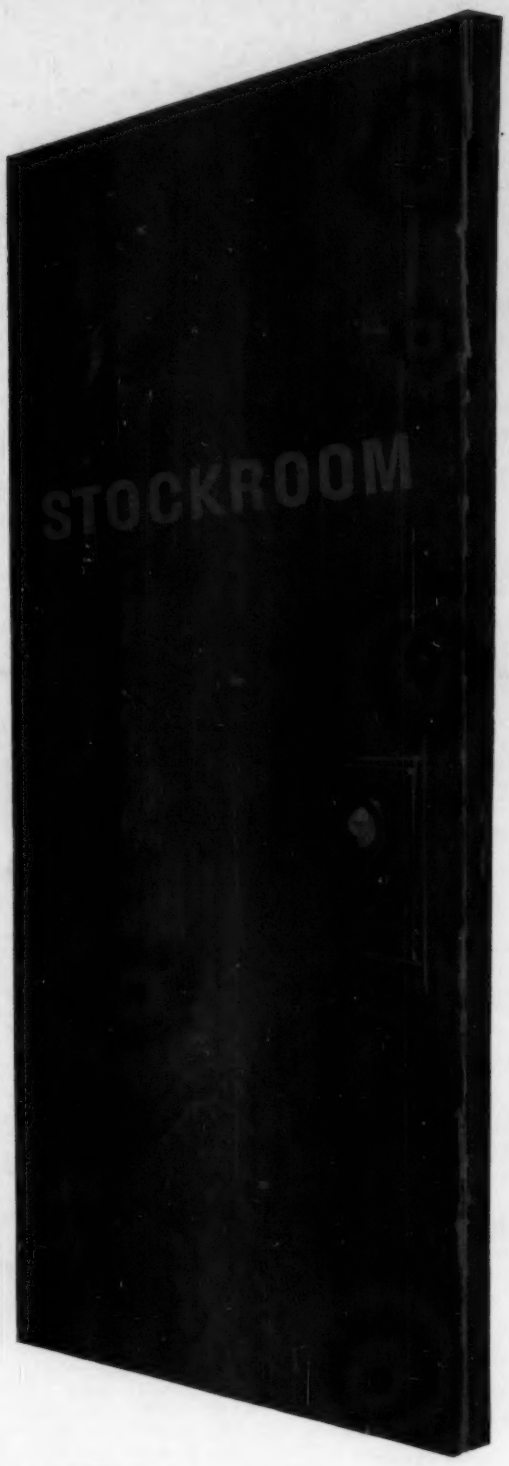

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